A REVIEW OF CANE DIFFUSION AT SEZELA AND UMZIMKULU SUGAR FACTORIES

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Abstract

The cane diffusion process is widely used in the South African sugar industry for extraction purposes. This paper reviews the operation and maintenance of three stationary screen, horizontal bed diffusers installed at Sezela and Umzimkulu sugar factories. Two identical units were installed at Sezela factory in the 1983/84 season and a similar unit was installed at Umzimkulu factory in the 1991/92 season.

All three diffusers produced extraction efficiencies above 98% and, in the 2005/06 season, all three units produced extractions of above 98,5%. The Umzimkulu diffuser was able to produce high extraction efficiencies at higher than design cane throughputs. All three diffusers operate at high imbibition rates of around 440% imbibition on fibre.

The highest cost maintenance item is chain replacement. The average life of a chain has been around 14 years. The chain pins and bushes need to be replaced on average every 6-8 years. A negative aspect of cane diffusion is the extraction of acetic acid and corrosion of downstream equipment. Corrosion is severe in vapour pipes, evaporator and pan domes. However, it can be minimised by using corrosion resistant materials such as 3CR12 steel.

Keywords: cane diffuser, horizontal bed diffuser, extraction, diffuser chain, diffuser maintenance, diffuser corrosion, factory process

Introduction

Illovo Sugar Limited – Sezela factory converted to 100% cane diffusion in the 1983/84 season. Two identical stationary screen, slat type diffusers were installed. A similar diffuser was installed at Illovo Sugar Limited – Umzimkulu factory in the 1991/92 season, although the Umzimkulu diffuser has a very simple cane preparation set-up compared with the Sezela units. High crush rates and high extraction performance have been recorded on the Umzimkulu diffuser. This paper reviews the operation and maintenance of these diffusers.

Description of the diffusers

The two diffusers (SZ1 and SZ2) at Sezela and the one at Umzimkulu (UK) are almost identical. A brief description of the diffusers is given in Table 1. All three installations are stationary screen, slat-type cane diffusers.

Table 1. Description of the diffusers.

Diffuser	SZ1	SZ2	UK
Screen length (m)	54	54	54
Screen width (m)	7,5	7,5	7,5
Screen area (m^3)	405	405	405
No. of chains	10	10	10
Chain drive power (kW)	55	75	55
No. of stages	12	12	12
No. of lifting screws	2x7	2x7	2x7
Heavy duty dewatering drum	yes	yes	yes
Original design	BMA	BMA	BMA
Original design rating (tch)	220	220	220

Although the diffuser units are similar, the configuration of the cane preparation equipment is different. Table 2 gives details of the three installations.

Table 2. Cane preparation equipment details.

Diffuser		SZ1	SZ2	UK
Cane leveller	: type	electric	electric	electric
	rpm	720	720	960
	clearance (mm)	1200	1200	800
	power (kW)	200	200	450
First knife	: type	electric	electric	turbine
	rpm	720	720	750
	clearance (mm)	600	600	10
	power (kW)	500	500	1250
Secondary knife	: type	turbine	turbine	–
	direction	reverse	reverse	–
	washboard	anvil plate	anvil plate	–
	rpm	450	450	–
	clearance (mm)	20	20	–
	power (kW)	1000	1000	–
Shredder	: type	turbine	turbine	turbine
	rpm	1200	1200	1200
	power (kW)	1850	1850	1850
	number of hammers	200	200	100

Extraction performance

All three diffusers produced good sucrose extractions of around 98% over the years. The 10-year average data for Sezela (combined) and Umzimkulu is shown in Table 3.

Table 3. Ten-year average extraction data.

Parameter	Sezela (combined)	Umzimkulu
Sucrose extraction	98,15	98,23
Tons cane per hour	417	244
Imbibition % fibre	391	458
Sucrose % cane	13,15	13,20
Fibre % cane	15,70	15,14
Pol % bagasse	0,79	0,74
Moisture % bagasse	47,84	50,48

The 2005/06 crushing season was good for sucrose extraction for both factories when new season extraction records were established. The Sezela units produced a combined extraction of 98,51% and the Umzimkulu unit produced 98,58%, as shown in Table 4.

Table 4. The 2005/2006 crushing season extraction data.

Parameter	Sezela (combined)	Umzimkulu
Sucrose extraction (%)	98,51	98,58
Tons cane per hour	399	243
Imbibition % fibre	438	483
Sucrose % cane	13,81	13,13
Fibre % cane	15,62	15,26
Pol % bagasse	0,68	0,60
Moisture % bagasse	47,0	48,9

Typical brix, pH and temperature profiles for the Umzimkulu diffuser are shown in Table 5.

Table 5. Typical brix, pH and temperature profiles of the Umzimkulu diffuser.

Cell	SJ	1	2	3	4	5	6	7	8	9	10	11	12
Brix	10,0	6,4	5,3	4,3	3,5	2,8	2,4	1,6	1,3	1,1	0,9	0,8	0,7
pH	5,1	5,2	5,3	5,4	5,5	5,7	5,8	5,8	5,9	5,9	6,0	6,0	6,0
Temp.°C	84	89	92	93	94	93	92	94	90	92	81	82	80

Operating factors affecting sucrose extraction

Imbibition rate

The control parameter that has the biggest effect on extraction is imbibition % fibre. At Umzimkulu extraction benefit was achieved even at imbibition % fibre rates above 500. There was no measurable difference between adding part of the imbibition at the dewatering mills or into the diffuser. Figure 1 shows a trend between imbibition and extraction at Umzimkulu for the 2000/01 season.

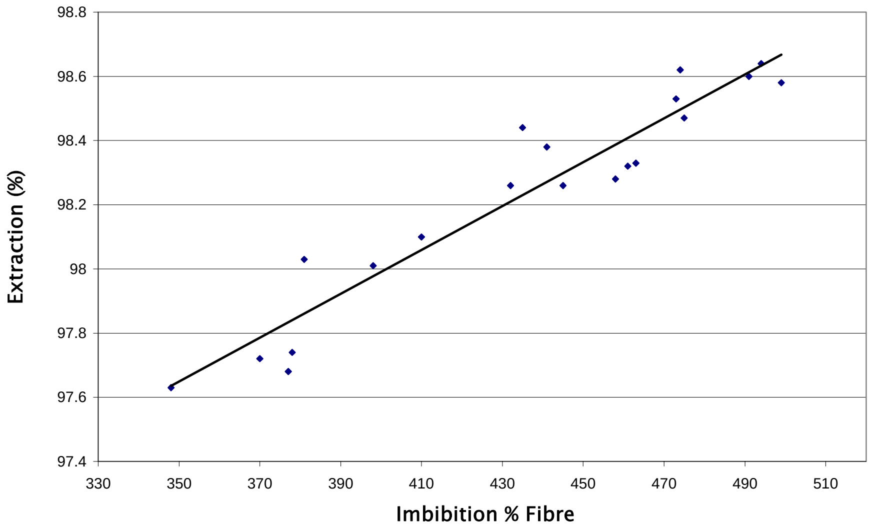

Figure 1. The relationship between imbibition and extraction at Umzimkulu.

Temperature

Initially it was believed that the diffuser temperature should be maintained on the low side; however, McMaster and Ravnö (1975) showed that losses due to thermophilic bacteria were high, and temperature should not drop below 80°C in the diffuser. For this reason, both factories maintain temperatures above 80°C. Scalding juice is maintained between 95-98°C after the heaters to obtain a draft juice temperature around 75°C. Although not quantifiable, the authors believe that a scalding juice temperature of 98°C and a flowrate of 600 tons per hour aids the sucrose extraction process.

pH control in diffusers

Initially it was believed that pH adjustment with milk of lime was important to minimise inversion in the diffuser. The diffusers were installed with two liming stations per diffuser. Each liming station had three outlets that introduced lime to three stage pumps. In total each diffuser had six liming points.

To achieve an average cell juice pH of 6,2 the individual cells where lime was added was 'spiked' to about 7,5. Beckett and Graham (1989), Schäffler *et al*. (1988) and Cox *et al*. (1993) showed that liming diffusers increased acetate production. This research, together with high levels of vapour space corrosion, led to lime addition being discontinued. The operating philosophy that was adopted was that poor pH control was worse than no control. The authors believe that loss of sucrose due to low pH inversion on extraction is minimal.

Cane preparation

Cane preparation was for many years measured by preparation index (PI). Recently both Umzimkulu and Sezela factories changed to the Displaceability Rate Index (DRI) as described by Loubser and Gooch (2004). Optimum PI for good extraction ranged between 90-92 and optimum DRI ranged between 7 and 11. However, the best measurement of cane preparation is visual, and must be such that it allows the required imbibition to be applied with sufficient wetting of the bed. The philosophy at both factories is to increase or decrease preparation according to fluid retention in the diffuser bed. The authors believe that maximum contact time between the solid and liquid fractions is very important for extraction.

Another very important aspect of cane preparation is that the shredder should be set to run at steady speed, avoiding large fluctuations in speed and thus throughput. The shredder should be set as a metering device to give steady feed into the diffuser and thus an even bed level. The importance of an even bed level cannot be over-emphasised.

Bed level/bed speed

The average bed level around the mid-point of the diffuser is around 1,2 m, while at the cane feed area it is around 1,4 m. This is an operating parameter and is adjusted according to throughput and percolation characteristics of the bed. During rainy periods when percolation is poor a lower bed height/faster bed speed is required. Generally extraction improved with a higher bed level.

Bed level should be sufficiently high for the dewatering drum to give the bagasse bed a good squeeze. The heavy duty dewatering drum, which weighs about 40 tons, is an important dewatering device.

Scalding juice rate

All three diffusers operate at an average scalding juice flow rate of 600 tons per hour and a temperature of 95-98°C. The scalding juice is normally split between the scalding juice tray and the back plate where the prepared cane falls into the diffuser. It is important that the scalding juice is applied as close as possible to the cane feed into the diffuser. The Umzimkulu diffuser was retrofitted with an adjustable piano plate to ensure good feed distribution across the diffuser.

Scalding juice performs three important functions. The temperature of 95-98°C helps rupture juice cells that are not opened by cane preparation, the temperature and flow rate are required to produce a draft juice temperature of 75°C and the flow rate is required to flatten the cane feed into an even bed inside the diffuser.

Mud recirculation

Due to the lower suspended solids in mixed juice ranging between 0,10 and 0,20% for the Sezela and Umzimkulu factories, filter station operation has been difficult. The slimy mud is not conducive to good filtration in conventional mud filters. Mud thickening in the clarifier boot takes a long time and mud consistency is very variable. The coarse diffuser bagasse produces poor bagacillo quality and filter operation is generally difficult. Therefore mud recycle to the diffuser as described by Meadows *et al*. (1998) is a sensible and practical solution.

The advantages of mud recycle are zero filtercake losses, decommissioning of the filter station and elimination of microbiological and spillage losses across the filter station. Added benefits are thermal efficiency due to zero filter wash water, zero bagacillo usage and fuel value of filtercake. The zero filter wash water allows more imbibition water for the same evaporator capacity. Umzimkulu factory started recirculating clarifier mud to the diffuser in the 1999/2000 season. After initial problems and diffuser operator resistance, the practice is now well established at this factory. The thermal efficiency is clearly visible in Umzimkulu's huge surplus bagasse pile, despite a season average imbibition % fibre rate of 483 in 2005/06. This factory stays on bagasse generated electricity during weekend shuts and season-end boil offs. An added advantage of mud recycle is a clean smelling factory. In Umzimkulu's case there is another benefit of mud recycle in that diffuser cell pH increases from an average of around 5,5 to 5,8 across the diffuser.

The Sezela factory has also tried clarifier mud recycle, although the authors were not at Sezela when it was evaluated. The operators were very negative about the concept and stated that the diffusers flooded extensively. The practice was discontinued and the recycle equipment was removed, thus there is no opportunity to revisit this practice. The reason for the extensive flooding was not clear. However, there are some equipment differences between the two factories. The Sezela diffusers have two cane knives before the shredder, whereas the Umzimkulu diffuser has a single cane knife before the shredder. The Umzimkulu clarifier is a long retention time unit, whereas the Sezela clarifiers are short retention time units. The authors are not implying that these were the causes of the extensive flooding, but are merely stating the differences between the factories.

Some mechanical problems experienced with the three diffusers

Bagasse conveyors

At both factories the bagasse handling system had to be modified to handle the coarser bagasse produced by the diffusers. Bagasse transfer chutes, boiler chutes and boiler feeders had to be modified. Bagasse belt speeds had to be increased and transfer chutes had to be enlarged. This was a trial and error exercise and took a number of seasons to be perfected.

Dewatering mills

Initially all three diffusers produced high final bagasse moistures. In the early seasons after the diffuser installation staff had to modify dewatering mill settings away from conventional milling settings. The hot bagasse and the high amount of easily squeezable liquid in the bagasse exiting the diffuser needed changes to Donnelly chute and mill settings. Both factories now produce bagasse moistures below 50%. Umzimkulu has 72 inch and 84 inch conventional three-roller mills with feed rollers in series. The Sezela units were originally installed with two 84 inch heavy duty seven-roller pressure feed mills of Walker design, part of the old milling tandem. These units worked well on the milling tandem but were very troublesome on diffuser dewatering duty.

The main mechanical problem was bursting of the pressure feeders. Mill staff changed these units to conventional three-roller mills with a feed roller and operate the two units per diffuser in parallel operation. The modification was very successful.

Diffuser drive gearboxes

The Sezela units were originally installed with shaft mounted epicyclic gearboxes with four planetary gears around the sun gear. The four planetary gears were driven by four direct current (DC) motors. These gearboxes were very troublesome. The existing DC technology at the time of installation made synchronisation difficult and the individual motors were prone to hunting and gear damage.

These gearboxes were replaced with conventional milling tandem reduction gears driven by alternating current (AC) variable speed drives. The epicyclic gearboxes had a huge space saving advantage but were not suitable for diffuser drives at that time. The Umzimkulu diffuser was installed with a set of conventional milling tandem reduction gears and AC variable speed drive.

Diffuser chain

The chains used to drag the prepared cane inside the diffuser require expensive maintenance and replacement. The Sezela and Umzimkulu experiences have shown that the chain pins and bushes need to be replaced every 6-8 years, and the chain needs to be replaced every 12-16 years.

Initially all three diffusers were installed with wooden return runners underneath the diffuser. This was a poor choice of runner material, as sand particles become wedged in the wood and behave like abrasive sandpaper. Wear was visibly more on the non-working face of the chain, i.e. that part in contact with the wooden runner. The outside runners were changed to steel runners slightly softer than the chain. In January 2006, a new chain was installed on the

Umzimkulu diffuser at a cost of R6,2 million. The chain runners inside the diffuser require replacement every two seasons. This is an important maintenance function, as worn runners can cause bagasse particles to lodge themselves between the chain and runner and eventually lift the chain off the drive sprockets. The drive sprockets need to be built up to the original profile every two to three seasons. An approved welding technique must be used and a qualified artisan under close supervision must do the work. It is also important that the earth lead of the welding machine is attached as close as possible to the sprocket to avoid electric current arcing of the drive shaft bearings.

It is recommended that all future installations have the return chain on idlers to avoid dragging a hot, dry chain on a runner. A retrofit option was investigated for the three diffusers but proved difficult to fit in the short time available in the off-crop. Diffusers elsewhere in the industry successfully run the return chain on idlers. Dripping cold water as chain lubricant has been successfully implemented at Umzimkulu. However, this option is messy and the drip pipes need constant attention and cleaning. The use of hot water is not recommended as it evaporates very quickly.

Boiler tube erosion

The filtering action inside the diffuser traps sand particles, and diffuser bagasse has a higher sand content than milling bagasse. This sand is picked up by the combustion gases in the boilers, and boiler tube erosion by the 'sandblasting' effect of the combustion gases is of real concern. Tubes need to be carefully shrouded and both factories had to install stainless steel shrouding in high erosion areas. New boilers need to be of single pass design to lower the gas velocity through the tube bank and Sezela successfully converted a multipass boiler to a single pass boiler. Boiler maintenance is generally very high at both factories.

Vapour space corrosion

One of the disadvantages of diffusion is the extraction of impurities especially acetic acid which volatise in the process and release acetic acid. This causes major corrosion damage to diffuser roofs, vapour pipes, condensate pipes, evaporator and pan domes, and has been a serious problem at both factories.

A number of studies show the formation, volatilisation and condensation of acetic acid from diffuser juices. Schäffler *et al*. (1988) reported that lime addition to diffusers appeared to have a definite effect on acetic acid level in diffuser juices. Beckett and Graham (1989) showed that high lime concentration increases acetate production in a diffuser. Cox *et al*. (1993) found that acetic acid in vapour selectively condensed before water vapour and the area of first condensation had high levels of acetic acid.

Liming on the three diffusers has been discontinued and high corrosion areas have been replaced with corrosion resistant 3CR12 material. Plant observations confirm the findings of the above authors. For example the steam chest on a juice heater only corrodes around the steam (vapour) entry. The corrosion is highest on vessels that use vapour II, followed by vessels on vapour I. Vapour III and IV pipes and calandrias also show very high levels of corrosion.

Effect of diffuser juice on sugar quality

Rein (1995) states that, on average, diffuser juice colours are about 25% higher than those from a milling tandem and that starch content is much lower. Koster (1995) states that diffuser factory raw sugar colour was 30% higher, affinated sugar colour was 36% higher and starch was 25% lower than in sugar from milling tandem factories. Koster also showed that, at Umzimkulu, juice, syrup and sugar colours increased after the installation of the diffuser. This is shown in Table 5.

Table 5. Juice and sugar colours before and after the diffuser installation at Umzimkulu (Koster, 1995).

Product	Milling (1985-1990)	Diffusion (1991-1995)
Clear juice colour	21 700	28 100
Syrup colour	22 200	30 000
VHP sugar colour	1 200	1 900
VHP affinated sugar colour	600	1 000

Sezela and Umzimkulu sugar quality for the 2005/06 season is shown in Table 6, as reported by the Sugar Terminal.

Table 6. Sezela and Umzimkulu sugar quality for the 2005/06 season.

Parameter	Sezela	Umzimkulu
VHP sugar colour	1 387	1405
VHP affinated sugar colour	666	783
VHP sugar pol (°Z)	99,48	89,53
Starch (ppm)	108	113
Filterability (%)	63	56

Over the seasons both factories have adapted to the higher diffuser juice colour by washing the sugar to a higher pol.

Conclusions

The three cane diffusers have performed well at both factories. High extractions can be achieved with high imbibition levels. There is an extraction benefit up to 500% imbibition on fibre. Cane diffusers present an elegant solution to clarifier mud filtration and mud recycle to the diffuser is an established practice at Umzimkulu.

Chain maintenance is an expensive cost and complete chain replacement is required every 12-16 years. Vapour space corrosion is a problem at both factories. New boilers at diffuser factories need to be of single pass construction with low combustion gas velocities.

Sugar colours are generally higher than with milling tandems, and starch content is lower.

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