OPERATION OF A SATURNE DIFFUSER IN MAURITIUS

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ABSTRACT

The difficulties encountered with the operation of the Saturne diffuser installation are reviewed. The measures taken to overcome these difficulties as well as others aiming at improving the extraction performance of the installation are described. Results of experimental work undertaken in order to assess the general performance of the milling-diffusion plant are given.

INTRODUCTION

The Saturne diffuser installed at St Antoine factory was meant to replace the 3 intermediate mills of a 5-mill tandem. These 3 mills were installed in 1921 and recently were chiefly responsible for poor sucrose extraction by the tandem. In view of a need to increase the crushing capacity of the factory from around 100 to 125 tons cane per hour, these 3 mills were considered unsafe and inadequate. However, up to now, one of them, namely the fourth mill of the old tandem, has been kept in operation as a dewatering mill. The milling-cum-diffusion installation therefore consists of 1 first extraction mill followed by the Saturne and 2 dewatering mills in series as shown in Fig. 1, which is a schematic diagram of the preparation and extraction plant as at August 1973. The liquid flow paths as at the same date are shown diagramatically in Fig. 2.

The diffuser was designed to handle first mill bagasse at a rate corresponding to 150 tons cane per hour and was commissioned during the 2nd week of October 1971. Many technical difficulties were encountered with the operation of the diffuser and ancillary equipment, and it is the main object of this paper to review these difficulties and the measures adopted in an attempt to overcome them. In this connexion, the alterations made to the installation since 1971 are shown graphically in Fig. 3. The other object of this paper is to report on the experimental work carried out to appraise the extraction performance of the installation.

THE 1971 SEASON

No advance change in respect of operation of existing equipment had been planned in view of the intended change from milling to diffusion. It was thought more appropriate to take action only when found necessary. However, there was a strong feeling that the degree of cane preparation generally obtaining at the factory would not be suitable for efficient diffusion. Many poorly prepared pieces of cane and even some whole sticks generally found their way to the first extraction mill and passed on to subsequent extraction units insufficiently broken down. A first step to improve cane preparation was therefore taken whereby the direction of rotation of the 2nd set of knives was reversed, the knives being made to rotate in the unconventional direction. A noticeable improvement resulted from this change and this observation was confirmed by
pol in open cells figures which jumped from around 45 to about 60, although a few whole sticks still managed to get through the preparation station.

The diffuser was commissioned shortly afterwards and from the very start difficulties in keeping the juice levels within the design limits were experienced. The juice level in the maceration section of the diffuser would at times rise so much that thin juice would overflow through the bagasse discharge opening. At other times, the juice level would fall steadily, the zone of effective maceration being thereby reduced. Such occurrences were rather frequent and were
FIGURE 2. Schematic diagram of liquid flow paths.

1. 1st Extraction Mill
2. Diffuser
3. Dewatering device
4. Dewatering mills
5. Dewatering screens
6. Scalding juice tank
7. Recirculation juice tank
8. Surge tank
9. Primary Juice
10. Diffusion Juice
11. Drift Juice
12. To Clarification
<table>
<thead>
<tr>
<th>YEAR</th>
<th>1971</th>
<th>1972</th>
<th>1973</th>
</tr>
</thead>
<tbody>
<tr>
<td>Set Nr. 1</td>
<td>36 knives 985 rpm 186 kw (electric) 300 mm clearance</td>
<td>as in 1971</td>
<td>36 knives 720 rpm 280 kw (electric) 300 mm clearance</td>
</tr>
<tr>
<td>Set Nr. 2</td>
<td>Cane 44 knives (hook) 720 rpm 280 kw (electric) 20 mm clearance</td>
<td>Bridged Cane Cane 48 knives, 720 rpm 280 kw (electric), 20 mm clearance</td>
<td>Cane 48 knives 704 rpm 375 kw (turbine) 20 mm clearance</td>
</tr>
<tr>
<td>Set Nr. 3</td>
<td>None</td>
<td>268 knives 1,050 rpm 60 kw (electric)</td>
<td>as in 1972</td>
</tr>
</tbody>
</table>

**FIGURE 3.** Diagrammatic representation of major alterations.
the direct result of variations in the degree of preparation of the cane and in sudden, short variations in throughput rate. Variations in crushing rate would result in corresponding variations in the extent of filling of the baskets. On the other hand variations in degree of preparation would alter the compaction of the bagasse. The combined effects of these two would cause percolation characteristics to vary widely. The basic cause of the trouble was, however, the highly heterogeneous nature of the cane supplies.

It seems fitting to mention here that cane is supplied to the factory by some 2 400 growers and that at least a dozen cane varieties are grown in the factory area under widely contrasting agronomic conditions. Fibre content of cane therefore often varies widely from one cane consignment to another, causing wide variations in degree of preparation and crushing rate.

Such a situation results in wide fluctuations in flow rates of diffusion juice going to process. Bagasse screening from the percolation section of the diffuser were originally sent, together with the diffusion juice, to be pumped off. Reductions in flow rates of diffusion juice often resulted in choking of the service pump which on frequent occasions had to handle almost only bagasse. The point of discharge of the screenings was therefore transferred to the re-circulation juice tank and there was no further pumping trouble.

The early extraction performance figures were rather unsatisfactory and analysis of the screening fractions of diffuser discharge and final bagasse showed that the poor performance could be partly accounted for by the high pol content of the coarser fractions.

Steps were therefore taken to reduce the proportion of these coarse fractions. Deflection plates were fixed to the sides of the cane carrier ahead of the 2nd set of knives so as to reduce the clearance between the cane carrier sides and the knives at each end of the set. This eliminated some of the whole stalks which had

FIGURE 4. First mill bagasse at St Antoine factory (1971).
managed to get as far. The physical condition of the 1st mill bagasse generally obtaining after this modification may be seen in the photograph shown in Fig. 4, and as may be observed, there was still room for improvement.

As regards extraction performance, no noticeable improvement followed this alteration to the preparation department but at this time no more could be done.

Efforts to improve on extraction performance were therefore directed elsewhere. Up to then, about two-thirds of the total amount of imbibition water had been applied at the top of the diffuser and the remainder shared between the 2 dewatering mills. The average values of pol % bagasse and pol lost in bagasse % fibre were then 2,66 and 5,74 respectively.

The practice in respect of imbibition water was reversed from then on. As much of the imbibition water as practically possible was utilised in conjunction with the dewatering mills. The limiting factors in this connexion were, on the one hand, the absorbent capacity of the bagasse going to the 1st dewatering mill and, on the other hand, the ability of the last mill to grip wet bagasse. In practice, it was found possible to apply about two-thirds of the total amount of imbibition water at the dewatering mills and the remainder at the diffuser.

A sharp improvement followed this change in practice. Pol % bagasse dropped markedly: the average figure for the second half of the season was 2,21 and pol lost in bagasse % fibre for the corresponding period fell to 4,74.

During this first season, a fair amount of trouble was experienced with the dewatering device. The full potential of this equipment of excellent design could not be utilised because of mechanical mishaps. Transverse welds on the smaller cylinder failed on several occasions and the maximum allowable load could not consequently be applied to the diffuser discharge bagasse. Moisture content of the latter could not therefore usually be brought down below 78%. Under these circumstances, it was found very difficult to adjust the speed of the device to ensure its smooth operation. At a load of about 65% of the maximum allowable, excessive lift of the smaller roller caused diffuser discharge bagasse to be swallowed in a short period of time, the device then remaining idle during the rest of the cycle. Efficient use of the imbibition water, which was partly

<table>
<thead>
<tr>
<th>TABLE 1. Chemical control results at St Antoine factory.</th>
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<tr>
<td>--------------------------------</td>
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<tr>
<td>Sucrose % cane</td>
</tr>
<tr>
<td>Fibre % cane</td>
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<tr>
<td>Tons cane / hour</td>
</tr>
<tr>
<td>Imbibition % cane</td>
</tr>
<tr>
<td>Imbibition water % fibre</td>
</tr>
<tr>
<td>Moisture % bagasse</td>
</tr>
<tr>
<td>Fibre % bagasse</td>
</tr>
<tr>
<td>Pol % bagasse</td>
</tr>
<tr>
<td>Pol lost in bagasse % fibre</td>
</tr>
<tr>
<td>Extraction</td>
</tr>
<tr>
<td>Reduced extraction @ 12,5%</td>
</tr>
<tr>
<td>fibre</td>
</tr>
<tr>
<td>Pol lost in scums % cane</td>
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</table>
applied at the bagasse discharge side of the device, was consequently impaired. This most certainly accounts for the rather unspectacular extraction performance figures shown in Table 1 for the season.

The 1972 Season

Because of the percolation difficulties encountered in 1971, much attention was given to the cane preparation department during the off season.

The 2nd preparation set was modified according to a design by Sucatlan Engineering. Adjacent knives were bridged at their outer end by a thin sharp cutting blade in a staggered arrangement. The set was in a position to provide a practically uninterrupted cutting front perpendicular to the advancing cane. This set was designed to rotate in the unconventional direction. A third set of 268 thin bladed knives, also designed and supplied by Sucatlan Engineering, was installed about midway down the feeding chute of the first extraction mill. This additional set, designed to run at high peripheral speed through a thin blanket of already prepared cane, was meant to cut selectively the longer pieces of cane. The objectives sought with these modifications and addition were to obtain neatly cut cane particles of rather uniform size so as to enhance percolation and extraction.

However, this objective could not be met due to serious trouble with both sets of knives. Chopped up cane packed in between the bridged pairs of knives and the increased resistance to motion which ensued caused the driving motor to stall.

The transverse cutters had to be removed and the set was subsequently operated as in 1971 but with addition of one extra pair of knives on each end of the shaft.

With the turbulence created by the 3rd set of knives, the packing effect of the prepared cane falling down the first extraction mill feed chute was lost. Feeding difficulties were consequently experienced at this mill and its extraction performance became very erratic. Moreover the automatic feed control system of this same mill could no longer be operated and frequent chokes of the mill and of the 3rd set of knives resulted. This preparation set had consequently to be moved to the top of the first mill chute and set at a clearance of 150 mm whence much of its potential was not utilised.

Even with the third set of knives in that new position, the automatic feed control system of the first mill could not be made to work satisfactorily. In that system, the cane carrier speed was adjusted according to the level of prepared cane in the mill chute as detected by a photoelectric cell towards which a beam of light was directed. The photoelectric level detector was replaced by another one working on the same principles but in conjunction with ultrasonic waves. Following this, there was only a slight improvement in the feeding of the 1st mill. This is reflected by the drop in 1st mill extraction in 1972 as shown in Table 2.

During the off-season, the small roll of the dewatering device had been repaired and stiffened so as to allow for more pressure on the bagasse. However, design pressures could not be reached at first due to a faulty hydraulic circuit. This was eventually fixed but it then proved impossible to apply full load to
the bagasse because of limited torque at the hydraulic motors. The load had therefore to be limited to about 80% of the maximum allowable.

After some time of operation at this loading, cracks appeared on the perforated drum and the load on the bagasse had to be further reduced. During this 1972 season therefore, the potential of the dewatering device again could not be fully utilised.

Many changes were made in the imbibition water and press water distribution paths. During 1971, imbibition water had been shared between the 2 dewatering mills and the diffuser. Press water from the dewatering device and the 2 dewatering mills were mixed together before pumping back to the diffuser. From a comparison of the brix of press water extracted at the various pressure stages, it was observed that the juice from the last mill front pressure was about 1° brix lower than the other fraction. This particular fraction was therefore sent separately to the topmost part of the diffuser without screening or reheating. The rest of the press water was introduced lower down as indicated in Fig. 2. All the imbibition water was shared between the 2 dewatering mills.

During the early part of the season, the overall extraction had been generally below expectation. Analysis of bagasse leaving the first dewatering mill highlighted the poor performance of this particular unit. Roll slip and polishing of roller surface, problems hitherto practically unknown, came to light. To improve grip, pea sized welding beads were deposited on the surface of the feeder roller of both dewatering mills. In addition mill speeds were carefully controlled to ensure floating of the top rolls at all times. A noticeable improvement resulted from these combined actions.

The major problem yet unsolved by the end of this second season was that of poor percolation. Juice levels were generally high and juice overflow through the by-pass was a common occurrence. Despite this however, the overall performance for the season was better than that of the previous year as can be judged from Table 1.

**THE EARLY 1973 SEASON**

During the 1972-73 off-season, further attention was given to the cane preparation department. A heavy curved washboard type steel plate was fitted over the 2nd set of knives, the feeding of which was assisted by a powered drum as shown in Fig. 3. The 280 kW electric drive of the same set was transferred to the first set of knives and a 375 kW steam turbine was installed to replace it. No change was made in respect of the 3rd set of knives.

When the season started, it was found impossible to handle more than 75 tons cane per hour with the new arrangement, as beyond this capacity, the modified unit choked. The feeder drum was therefore removed and following this the cane preparation department has been able to deal with 115 tons cane/hour.

With this new arrangement, the preparation improved considerably compared to the previous years, the prepared material looking much like shredded cane.

The feeding of the first mill has now become more regular following installation of a new feed control system and the performance of this extraction unit has consequently improved.
Two modifications were made to the diffuser in the off-season. Firstly, the point of entry of the scalding juice was lowered by about 4 m to reduce the dynamic packing effect of the juice on the bagasse fed into the diffuser baskets. The purpose of this was to reduce the risk of overfilling the baskets with tightly packed bagasse. When this occurred in the past, it worked like a displacement pump, scooping juice out of the diffuser; furthermore bagasse would not discharge freely from the baskets. In the other modification, the grille on the juice exit side of the diffuser was replaced by a perforated plate so as to reduce the amount of bagasse entrained with the juice. This new screen blinded rapidly, more particularly at its lowest part which resulted in a rise in juice level at the exit end of the maceration section of the diffuser.

The frequent overflowing of thin juice through the by-pass on the bagasse discharge side of the diffuser since the start of the season may be partly attributed to this effect. To overcome this, the perforations on the lower end of the screen were enlarged and overflowing has been only occasional since then. This improvement may however be also attributed to the fact that cane processing rate was reduced at the same time due to shortage of capacity in the pan boiling department of the factory.

During the off-season, overhaul of the dewatering device revealed that the hydraulic motors at each end of the driven cylinder were opposing each other. This situation was corrected and the device has operated without any problems since the beginning of the season, bringing the moisture content of the bagasse down to about 72%.

At the time of writing, the diffuser has been operating for only 5 weeks since the opening of the season and the industrial results for this early period are shown in Table 1.

In the course of this 1973 crop, two additions are planned. Firstly a gamma ray system for controlling the filling of the baskets is to be installed. The aim of this is to achieve uniformity in the volume of bagasse in the baskets by varying the cycle times rather than keeping cycle times constant as practised so far. Secondly, an additional dewatering device of the same design as the existing one but of shorter length is to be installed shortly. This unit is expected to replace eventually the first dewatering mill. The set up will then consist of 1 first extraction mill, followed by the diffuser, 2 dewatering devices in series and 1 drying mill.

**ASSESSMENT OF DIFFUSER PERFORMANCE**

*Pol extraction*

The early part of the 1971 season was devoted to the assessment of the extraction performance of the milling tandem at St Antoine. Extractions of various mills were calculated from pol: fibre ratios, these 2 parameters being determined by direct analysis of prepared cane and bagasse leaving the various units of the tandem. The same technique of analysis was also used later in the 1972 campaign. The average results of the investigations are shown in Table 2.

During the 1972 campaign retention times of bagasse in the diffuser ranged from 23 to 30 minutes whilst temperatures in the maceration section ranged from 61 C to 75 C. No correlation could be found between retention times and temperature on the one hand and extraction performance on the other hand. It should be stressed, however, that because of the rather narrow range of tem-
temperature and times concerned, any effect on the extraction performance of the diffuser was likely to be so small as to be undetected by the experimental procedure utilised. Moreover, although every precaution was taken to ensure that cane and bagasse were sampled from corresponding consignments, sampling errors were introduced because of the very heterogeneous nature of the materials involved.

"Difficult" Brix extraction

Throughout the 1972 season, extensive efforts were made to assess diffuser performance in respect of extraction of "difficult" or bound brix. The technique used for determining "difficult" brix was a slight modification of that described by Ferguson et al. Determinations were made on 250 g samples and iodide concentrations were determined volumetrically using an adsorption indicator (Rose bengal). "Difficult" brix determinations were also carried out at 2 conventional milling factories for sake of comparison. The average results of these investigations are graphically represented in Fig. 5.

The rather poor performance of the first extraction mill at St Antoine resulted in the diffuser having to deal with bagasse having a higher "difficult" brix content compared to the 2 milling factories. Consequently, the diffuser performance may not readily be compared with the performance of individual mills at the 2 milling factories. In order to establish a fair comparison between

<table>
<thead>
<tr>
<th>Pol extracted %</th>
<th>1971</th>
<th>1972</th>
</tr>
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<tbody>
<tr>
<td>Pol in cane</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1st mill</td>
<td>63.2</td>
<td>62.8</td>
</tr>
<tr>
<td>Diffuser and dewatering device</td>
<td>-</td>
<td>17.2</td>
</tr>
<tr>
<td>2nd and 3rd mills combined</td>
<td>23.6</td>
<td>-</td>
</tr>
<tr>
<td>4th and 5th mills combined</td>
<td>6.7</td>
<td>13.5</td>
</tr>
<tr>
<td>Overall extraction</td>
<td>93.5</td>
<td>93.5</td>
</tr>
<tr>
<td>Reduced extraction</td>
<td>95.1</td>
<td>95.3</td>
</tr>
</tbody>
</table>

FIGURE 5. Evolution of "difficult" brix % fibre along tandem of three extraction plants.
the milling-cum-diffusion plant and straight milling tandems, the specific extractions of the individual units of the 2 milling factories were therefore calculated and used to construct the hypothetical brix curves shown in Fig. 6. "Difficult" brix % fibre values used as starting point for these hypothetical curves are those obtaining in the diffusion factory.

"Difficult" brix % fibre values used as starting point for these hypothetical curves are those obtaining in the diffusion factory.

From a comparison between "difficult" brix % fibre curves for St Antoine (Fig. 5) and the corresponding hypothetical curves for the milling factories (Fig. 6), it is apparent that the diffuser is equivalent to 1,1 mills at Factory A and 0,9 mills at Factory B.

However, if we consider the diffuser together with the first dewatering mill, the equivalence is 2,9 mills at Factory A and 1,9 mills at Factory B.

**Effect of bagasse particle size**

During the 1972 season, attempts were made to investigate effects of bagasse particle size on extraction performance of the diffusion plant. However, it proved very difficult to separate diffuser discharge bagasse into different size fractions by dry sieving. The investigation was therefore confined to the first mill and final bagasse. The results obtained are summarised in Table 3.

As may be observed from this table, first mill bagasse was composed of a large proportion (39,8%) of fines consisting nearly essentially of pith. These particles are the most efficiently de-sweetened as may be observed from Table 3. However, they are most likely to cause percolation difficulties by filling up the space between the larger bagasse particles.

**TABLE 3.** Relationship between particle size and Pol content of bagasse.

<table>
<thead>
<tr>
<th>Particle size</th>
<th>Retained on 25,4 mm mesh</th>
<th>Retained on 9,5 mm mesh</th>
<th>Retained on 4,8 mm mesh</th>
<th>Passing through 4,8 mm mesh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Origin of bagasse</td>
<td>1st mill</td>
<td>Final</td>
<td>1st mill</td>
<td>Final</td>
</tr>
<tr>
<td>% by weight</td>
<td>10,9</td>
<td>3,7</td>
<td>39,2</td>
<td>27,0</td>
</tr>
<tr>
<td>Pol content %</td>
<td>8,5</td>
<td>4,0</td>
<td>8,1</td>
<td>3,1</td>
</tr>
</tbody>
</table>
Clarification, filtration and starch destruction effects

The above were investigated in the 1973 season. Daily samples of first mill and diffusion juice were analysed for starch, suspended matter and precipitable muds. The same analyses were carried out on primary and secondary juices at Belle-Vue factory adjoining St Antoine. Precipitable muds were determined as follows: juice was filtered through filter paper and filtrate was boiled and then limed to a pH around neutral; the precipitate so formed was collected by filtration and dried without washing. Corrections for dissolved solids adhering to the precipitate and filter paper were applied to weights of dry mud. The average results of the investigation are shown in Table 4.

**TABLE 4.** Comparison of juice quality.

<table>
<thead>
<tr>
<th>MILLING FACTORY</th>
<th>DIFFUSION FACTORY</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Primary juice</td>
</tr>
<tr>
<td>Starch % brix</td>
<td>0,093</td>
</tr>
<tr>
<td>Suspended solids % brix</td>
<td>2,22</td>
</tr>
<tr>
<td>Precipitable muds % brix</td>
<td>0,613</td>
</tr>
</tbody>
</table>

The low starch content of diffusion juice is a strong indication that starch hydrolysis takes place in the diffuser where temperature conditions are favourable to enzymatic action.

The low suspended solids and precipitable muds in diffusion juice are in agreement with the low filter cake % cane figures obtaining at St Antoine since the installation of the diffuser.

**GENERAL DISCUSSION**

The biggest problem yet to be solved at St Antoine is due to percolation difficulties in the diffuser. In this respect, the Saturne has been no exception compared to other diffusion installations.2,3,4

The physical condition of bagasse is the most important single factor affecting the efficiency of bagasse diffusers. It has been recently established by Rein5 that lixiviation plays a much greater role than diffusion proper in bagasse diffusers. Both lixiviation and diffusion theories call for the finest possible bagasse particle sizes for highest extractions. On the other hand, flow characteristics of juice through layers of bagasse set a practical limit to particle size. In view of this, the counterflow and complete maceration principles embodied in the Saturne diffuser design leave rather little latitude in respect of physical condition of bagasse. For this reason, the Saturne may be said to show a certain lack of flexibility in the face of variations in cane quality and throughput.

Concerning extraction performance, mill extraction and extraction ratio, which are generally used for assessing performance of extraction plants, may be quite misleading in connexion with diffusion installations on account of dependence of these performance parameters on calculated fibre % cane.
It has been reported that fibre figures calculated from bagasse weights obtained from the fundamental equation:

\[ \text{Bagasse} = \text{cane} + \text{water} - \text{mixed juice} \]

may be highly inflated due to loss of matter. Such losses may arise from evaporation enhanced by high temperatures obtaining in diffusion plants. In fact, it has been found at St Antoine, where bagasse is directly weighed by means of an Ohmart gamma ray weigher, that a discrepancy of the order of 20% exists between the true weight of bagasse and the calculated one. This large discrepancy may be attributed not only to evaporation but also to spillage.

In view of the above it would be more appropriate to judge extraction performance of the diffusion plant from Pol lost in bagasse % fibre. For the period 1965 to 1970 when straight milling was practised, Pol % fibre was 4.87 on average and the mean hourly cane throughput was 101.2 tons.

In 1972, the Pol lost in bagasse % fibre was 4.45 at a mean throughput of 105.5 tons per hour and for the early 1973 season corresponding figures were 4.71 and 109.7 tons per hour. From these figures, it may be said that so far the diffuser has enabled St Antoine to deal with a slight increase in capacity, at the same time improving slightly on the extraction performance of its previous milling tandem.

ACKNOWLEDGEMENTS

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REFERENCES