CALCULATION OF MILL SETTINGS

By G. G. ASHE

The following is a simplified method of getting approximate mill settings, using first principles. For the purpose of these calculations we assume that cane consists of three ingredients, i.e. fibre, sucrose and water. Also that the S.G. of fibre, sucrose and water is 1.35, 1.55 and 1 respectively. It is necessary to have these values so that volumes in cubic feet can be calculated. The figures used in the following calculations are those for the 84" x 39" mill at the Umfolozi Co-operative Sugar Planters' factory at Riverview.

The following figures are the expected averages for the season:

13% Sucrose (S.G.=1.55)
13% Fibre (S.G.=1.3)
74% Water (S.G.=1)

The cubic footage for 1 ton (2,000 lbs.) of cane can be calculated as follows:

Sucrose=2,000 lbs. x .13= 260 lbs.
Fibre =2,000 lbs. x .13= 260 lbs.
Water =2,000 lbs. x .74=1,480 lbs.

2,000 lbs.

Sucrose

The weight of sucrose is 260 lbs. and the specific gravity is 1.55. Therefore, in order to get the volume, we divide the weight by S.G.$\times$62.5, thus:

$$\text{Vol. of Sucrose/ton Cane} = \frac{260}{1.55\times62.5} = 2.69 \text{ cu. ft.} \quad \ldots\ldots (1)$$

Fibre

The weight of fibre is 260 lbs. and the specific gravity is 1.35. Therefore, in order to get the volume, we divide the weight by S.G.$\times$62.5, thus:

$$\text{Vol. of Fibre/ton Cane} = \frac{260}{1.35\times62.5} = 3.07 \text{ cu. ft.} \quad \ldots\ldots (2)$$

Water

The weight of water is 1,480 lbs. and the S.G. of water is 1. Therefore, in order to get the volume, we divide the weight by the S.G.$\times$62.5, thus:

$$\text{Vol. of Water/ton Cane} = \frac{1,480}{1\times62.5} \quad 23.7 \text{ cu. ft.} \quad \ldots\ldots (3)$$

We can summarise as follows:

Sucrose=2,000$\times$.13= 260 lbs.= 2.69 cu. ft.
Fibre =2,000$\times$.13= 260 lbs.= 3.07 cu. ft.
Water =2,000$\times$.74=1,480 lbs.=23.7 cu. ft.

2,000 lbs.=29.46 cu. ft.

So far we have worked on one ton of cane and as mill roll speeds are usually given in feet/minute we must now establish a crushing rate in tons per minute.

$$\text{Crushing Rate} = 170 \text{ tons cane per hour} = \frac{170}{60} \text{ tons cane per minute} = 2.83 \text{ tons cane per minute} \quad \ldots (4)$$

We now have to calculate the peripheral speed of the mill. In this example we have taken the average outside diameter of the three rolls, whereas the mean diameter of the top roll only is sometimes used.

The following figures and calculation are based on our No. 6 (last) mill.

Top	*Feed*	*Discharge*	*Average Diameter*
39"	39"	39"	39"

$$\text{Circumference} = \text{Dia.}\times3.14 = \frac{39\times3.14}{12} = 10.02 \text{ ft.}$$

Average revolutions per minute at which the mill runs =3.6 r.p.m. ..... (5)

Peripheral speed =Circumference$\times$r.p.m.
=10.02$\times$3.6
=37 feet per minute.......... (6)

Width of Roller =7 feet

Escribed Area =Peripheral speed$\times$Width of Roller
=37$\times$7
=259 sq. ft. .... (7)

Escribed area can be described as the area that the roller will cover if rolled on the floor for 3.6 turns.

From the graph shown in figure A it will be seen that we expect an extraction of 96.5% and a moisture of 49% from No. 6 mill. In order to achieve this it means that the bagasse passing out of this mill must contain only 3.5% of the original weight sucrose in the cane, all of the fibre and only have a moisture content of 49%. Therefore the volume of these three ingredients must be the volume passing through the discharge opening.

This volume is calculated as follows:

Sucrose

From (1) we see that the total sucrose weighed 260 lbs. and had a volume 2.69 cu. ft.

$\therefore$3.5% of this sucrose will weight 260$\times$.035 lbs.
=9.1 lbs......... (8)

The volume occupied by this sucrose will be
2.69$\times$.035 cu. ft.
=.094 cu. ft.

Fibre

The bagasse contains all the original fibre. Therefore from (2) we get weight of fibre which is 260 lbs. and has a volume of 3.07 cu. ft. .... (9)

Water

The water content of the bagasse is 49%. Therefore, the weight of water will be—

$$= \frac{(\text{weight of sucrose} + \text{weight of fibre}) \times 49}{51} \text{ lbs.}$$

$$= \frac{(9.1+260) \times 49}{51} \text{ lbs.}$$

$$= \frac{269.1 \times 49}{51}$$

$$= 258 \text{ lbs.} \quad (10)$$

One cubic foot of water weighs 62.5 lbs.

∴ Volume occupied by water

$$= \frac{258}{62.5}$$

$$= 4.14 \text{ cu. ft.}$$

∴ Volume of Bagasse = Vol. of sucrose + Vol. of fibre + Vol. of water

$$= .094 + 3.07 + 4.14 \text{ cu. ft.}$$

$$= 7.304 \text{ cu. ft./ton cane} \quad (11)$$

This volume is per ton of cane and we now have to multiply it by the volume factor worked out in (4) to get the volume per minute.

∴ Volume of bagasse/min. = 7.304 × 2.83 cu. ft./min.

$$= 2.07 \text{ cu. ft./min.} \quad (12)$$

This can now be termed the escribed volume per minute. In order to get the discharge opening we divide the escribed volume per minute (12) by the escribed area per minute (7).

$$\text{Discharge opening} = \frac{\text{Escribed Volume}}{\text{Escribed Area}} \text{ ft.}$$

$$= \frac{20.7 \times 12}{259} \text{ ins.}$$

$$= .96 \text{ ins.} \quad (13)$$

The discharge opening which we have calculated is the total opening and is measured from point to bottom of the grooves provided the grooving is the same on both rollers.

Set Opening

In order to take cane of fibre variations and also allowing for top roller lift the set opening is taken as 75% of the calculated opening.

Therefore set opening = .96 × .75 ins.

= 72 ins.

Say 23/32″ .... (14)

Feed Opening

From graph B it will be seen that the ratio of feed to discharge varies from 2 to 1 at the crusher to 1.5 to 1 on the last mill.

Thus, the set feed opening will be—

= .72 × 1.5 ins.

= 1.08 ins.

Say $1\frac{1}{16}$″ .... (15)

The settings for the remaining mills can be found in a similar way. The extraction and moisture figures will of course differ from mill to mill.

Graph "A"

This graph has been drawn using the average figures from over one hundred individual mill tests and is reproduced here as a guide to indicate what extraction can be expected from each unit. In the actual calculations higher extractions for each mill have been used than the average shown by the curve. Maximum and minimum figures are also plotted. As a check on the above figures, Noel Deerr states that no advantage can be had by squeezing the bagasse to a density of more than 76 lbs. to one cubic foot.

Check

From (8) Sucrose	= 9.1 lbs.	= .094 cu. ft.
From (9) Fibre	= 260 lbs.	= 3.07 cu. ft.
From (10) Water	= 258 lbs.	= 4.14 cu. ft.
	527.1 lbs.	= 7.304 cu. ft.

$$\therefore \text{Density of bagasse} = \frac{\text{Weight}}{\text{cu. ft.}}$$

$$= \frac{527.1}{7.304} \text{ lbs./cu. ft.}$$

$$= 72 \text{ lbs./cu. ft.}$$

This figure of 72 lbs./cu. ft. is only 95% of that stated by Noel Deerr but we have more than accounted for that by taking 75% of the calculated opening.

Trashplate

The sole object of a trashplate is to convey the bagasse from the feed roller to the back roller and therefore the clearance between the top roller and the trashplate should not be smaller than the feed opening, so as to allow the bagasse to pass freely from the front to the back. In the event of the trashplate being set too high, choking of the mill will occur and unnecessary power is lost due to the pressure of the top roller on the bagasse between the trashplate and top roller.

In order to prevent this we set the toe opening equal to the feed opening + $\frac{1}{4}$″, for mills with grooving over 1″ pitch, and for 1″ and below, feed opening + $\frac{1}{16}$″. The opening between the heel of the trashplate and the top roller should vary between $\frac{1}{2}$″ and 1″ greater than the toe opening, depending on the size of the mill. In our case we use 1″.

Therefore trashplate setting is as follows:

Toe opening = Feed opening + $\frac{1}{16}''$

$= 1\frac{1}{16}'' + \frac{1}{16}''$

$= 1\frac{1}{8}''$ .... (16)

Heel opening = Toe opening + 1″

$= 1\frac{1}{8}'' + 1''$

$= 2\frac{1}{8}''$ .... (17)

I would like to mention here that at Umfolozi during the last season not a single trashplate was renewed and on the 84″ × 39″ mill 800,000 tons cane was milled, or 130,000 tons fibre. The trashplates are made of semi-steel.

Bagasse

The following notes on bagasse may be of interest to engineers who are newcomers to the Sugar Industry.

Bagasse plays a big part in the engineer's life. He mills it all day and burns it all day in the boilers.

It depends on how well he mills it, just how good the extraction will be and how good it will be as fuel.

We will separate the bagasse into the parts that mean most to the engineer.

Bagasse consists of fibre, plus moisture plus brix.

Firstly, fibre. This is given as 13% on cane, that is for every 100 tons of cane crushed we get 13 tons of fibre.

Brix

Brix is a measure of solids in cane, or juice or bagasse. Some of the solids are soluble, like sucrose, and some are insoluble.

As we are dealing with bagasse let us take the milling figures for any day to illustrate roughly what it consists of:

(Umfolozi 5.7.62)

Bagasse % Cane	:	28.10
Fibre % Cane	:	12.5
Sucrose % Bagasse	:	1.83
Moisture % Bagasse	:	52.84
Fibre % Bagasse	:	44.47
Brix % Bagasse	:	2.69

These figures show that there is 28.10 tons bagasse to every 100 tons cane crushed and this bagasse can be separated into different parts as follows:

Moisture % Bagasse	:	52.84	:	14.85 tons
Fibre % Bagasse	:	44.47	:	12.5 tons
Brix % Bagasse	:	2.69	:	.75 tons
		100.00%		28.1 tons

That is to say that in every 100 tons of cane there is 14.85 tons water, 12.5 tons fibre and .75 tons brix or solids.

Let us go further with the above sample of bagasse and separate, again roughly, the sucrose part.

Of the 2.69 parts brix, 1.83 parts are sucrose,

or $\frac{.75 \times 1.83}{2.69}$ tons of sucrose = .51 tons sucrose

leaving (.75 — .51) tons other solids or .24 tons other solids.

To show how important it is to keep the moisture low let us use the same fibre % cane figure, the brix % bagasse figure and the sucrose % bagasse figure, but make the moisture 45% bagasse.

If we have 45% water and 2.69% brix, the remainder is fibre % bagasse, thus:

Fibre % bagasse = 100 — (45 + 2.69)

= 52.31%

The 52.31% fibre will still weigh only 12.5 tons. The tons of brix will now alter and our bagasse will now show a new weight, thus:—

Fibre	52.31%	:	12.5	tons
Moisture	45.00%	:	10.75	,,
Brix	2.69%	:	.64	,,
	100.00%		23.89	,,

Tons of sucrose left in bagasse will now be—

$\frac{.64 \times 1.83}{2.69}$

= .436 tons sucrose

leaving (.64 — .436) tons other solids or

.206 tons other solids

The difference in the weight of water is—

14.85 — 10.75 tons

= 4.1 tons of water

Taking the sucrose % cane as 13% the extraction in the first example with 52.84% moisture will be:

Subtract the loss of sucrose in bagasse from sucrose in cane.

Weight 13 — .51 = 12.49 tons sucrose in mixed juice

∴ Extraction $= \frac{\text{Sucrose in mixed juice} \times 100}{\text{Sucrose in cane}}$

$= \frac{12.49}{13}$

= 96%

In the example with 45% moisture the loss is .436 tons of sucrose.

∴ Sucrose in mixed juice

= 13 — .436

= 12.564 tons sucrose in mixed juice

∴ Extraction $= \frac{12.564 \times 100}{13}$

= 96.5%

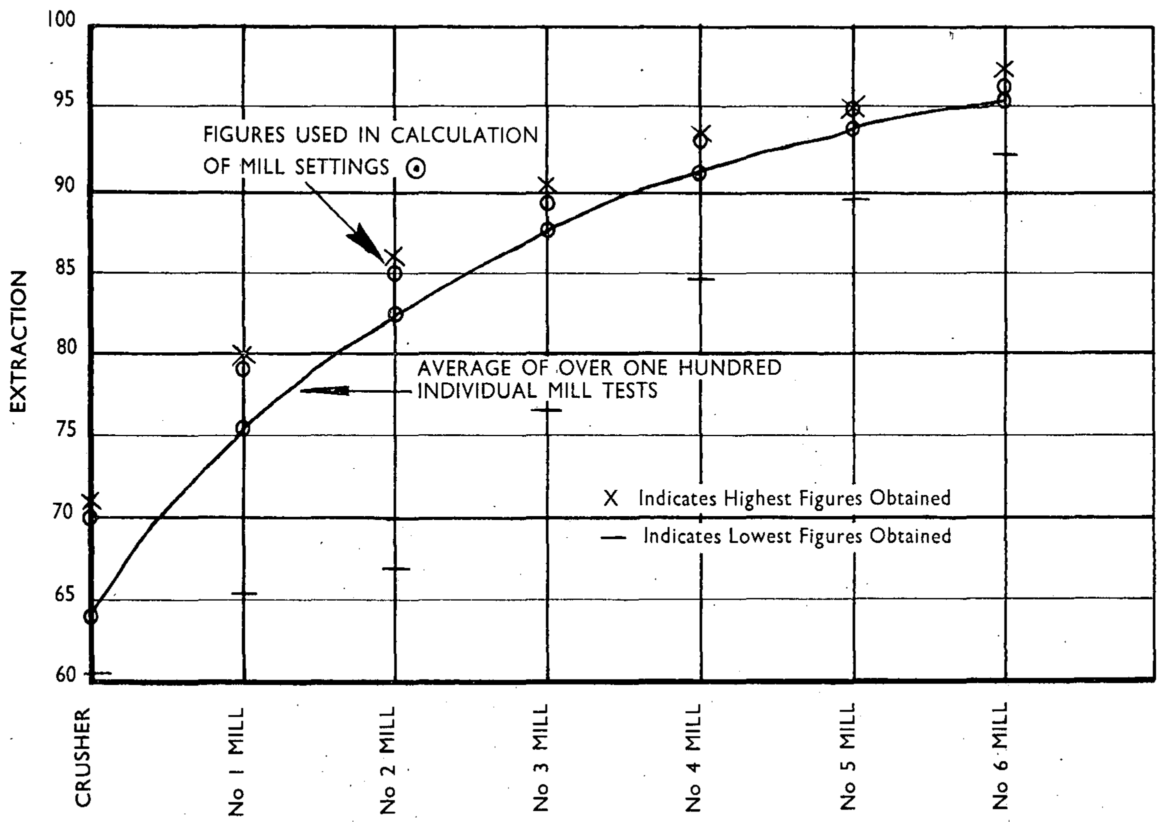
This shows an increase of .5% in extraction.

A very important observation from the above is the gain in heat value of the bagasse. In the first example we have to evaporate 14.85 tons of water per hour from the bagasse while burning it, whereas in the second example we have to evaporate 10.75 tons of water or 4.1 tons less per hour, thus effecting a considerable saving in fuel.

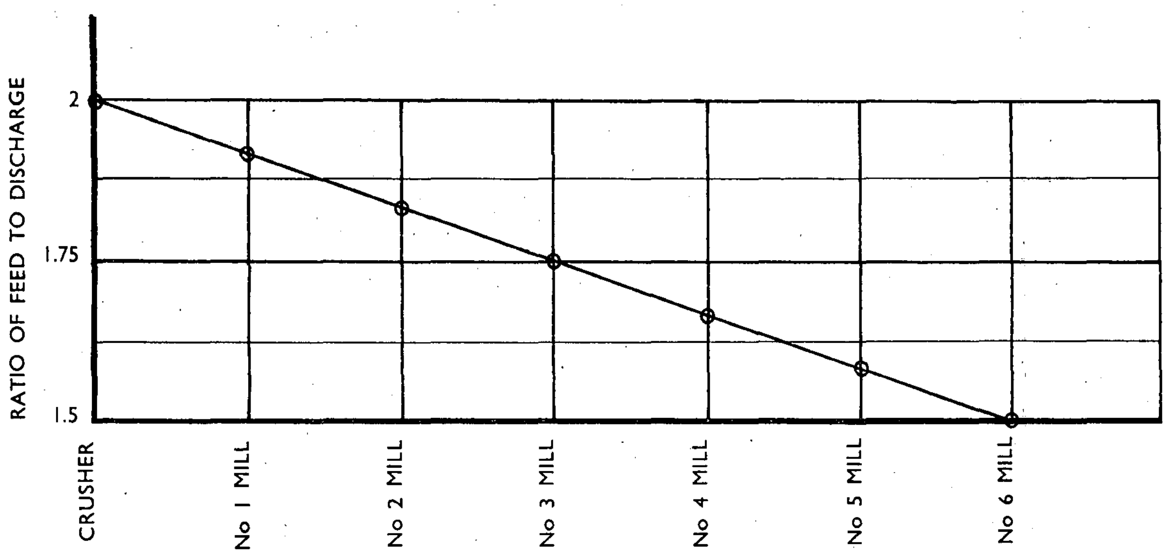
(All calculations have been done on slide rule.)

SUMMARY OF DATA REQUIRED FOR CALCULATING MILL SETTINGS

	Crusher	1st Mill	2nd Mill	3rd Mill	4th Mill	5th Mill	6th Mill
Top Roll Diameter	$39\frac{3}{4}$	39	40	37	37	39	39
Feed Roll Diameter	$40\frac{3}{4}$	$38\frac{5}{16}$	40	$37\frac{3}{8}$	39	39	39
Discharge Roll Diameter	$39\frac{15}{16}$	$37\frac{3}{4}$	$38\frac{7}{8}$	$37\frac{1}{2}$	$37\frac{1}{2}$	$38\frac{3}{8}$	39
Average Roll Diameter	40.14	38.56	39.62	37.29	37.8	38.8	39
Peripheral Speed .. .. .. (A)	30 ft./min.	30 ft./min.	30 ft./min.	30 ft./min.	30 ft./min.	30 ft./min.	37 ft./min.
Mill R.P.M.	2.86	2.96	2.89	3.08	3.03	2.95	3.6
Length of Rolls .. .. (B)	7 ft.	7 ft.	7 ft.	7 ft.	7 ft.	7 ft.	7 ft.
Escribed Area (A x B) .. .. .. (C)	210 sq. ft./min.	210 sq. ft./min.	210 sq. ft./min.	210 sq. ft./min.	210 sq. ft./min.	210 sq. ft./min.	259 sq. ft./min.
Extraction (See Graph "A")	70%	79%	85%	89%	93%	95%	96.5%
Moisture	60%	58%	55%	53%	51%	50%	49%
Weight of Fibre per Ton of Cane	260 lbs.	260 lbs.	260 lbs.	260 lbs.	260 lbs.	260 lbs.	260 lbs.
Weight of Sucrose per Ton of Cane	78 lbs.	54.6 lbs.	39 lbs.	28.6 lbs.	18.2 lbs.	13 lbs.	9.1 lbs.
Weight of Water per Ton of Cane	505 lbs.	435 lbs.	365 lbs.	326 lbs.	284 lbs.	273 lbs.	258 lbs.
Cubic feet of Fibre per Ton of Cane .. (D)	3.07 cu. ft.	3.07 cu. ft.	3.07 cu. ft.	3.07 cu. ft.	3.07 cu. ft.	3.07 cu. ft.	3.07 cu. ft.
Cubic feet of Sucrose per Ton of Cane (E)	0.87 cu. ft.	0.565 cu. ft.	0.404 cu. ft.	0.295 cu. ft.	0.1883 cu. ft.	.1345 cu. ft.	.094 cu. ft.
Cubic feet of Water per Ton of Cane .. (F)	8.1 cu. ft.	6.96 cu. ft.	5.84 cu. ft.	5.22 cu. ft.	4.54 cu. ft.	4.36 cu. ft.	4.14 cu. ft.
Total Vol. of Bagasse/Ton Cane (D+E+F) (G)	11.977 cu. ft.	10.595 cu. ft.	9.314 cu. ft.	8.585 cu. ft.	7.798 cu. ft.	7.564 cu. ft.	7.304 cu. ft.
Total Vol. of Bagasse/Min. (G×2.83) (H)	33.8 cu. ft./min.	29.9 cu. ft./min.	26.4 cu. ft./min.	24.3 cu. ft./min.	22 cu. ft. /min.	21.4 cu. ft./min.	20.7 cu. ft./min.
Discharge Opening in inches (H/C×12) (J)	1.93 cu. ft./min.	1.71 cu. ft./min.	1.51 cu. ft./min.	1.39″	1.26 cu. ft./min.	1.23″	.96″
Set Discharge Opening (J×.75) .. (K)	1.45″ ($1\frac{1}{2}$″)	1.28″ ($1\frac{9}{32}$″)	1.13″ ($1\frac{5}{32}$″)	1.04″ ($1\frac{1}{32}$″)	0.945″ ($\frac{31}{32}$″)	0.925″ ($\frac{29}{32}$″)	.72″ ($\frac{23}{32}$″)
Ratio of Feed to Discharge (See Graph "B")	2 : 1	1.92 : 1	1.83 : 1	1.75 : 1	1.67 : 1	1.58 : 1	1.5 : 1
Set Feed Opening .. .. .. (L)	2.9″ (3″)	2.46″ ($2\frac{15}{32}$″)	2.07″ ($2\frac{1}{16}$″)	1.82″ ($1\frac{13}{16}$″)	1.77″ ($1\frac{25}{32}$″)	1.46″ ($1\frac{15}{32}$″)	1.08″ ($1\frac{1}{16}$″)
Trashplate Toe Opening (L+$\frac{1}{4}$″) & (L+$\frac{1}{16}$)	$3\frac{1}{4}$″	$2\frac{5}{8}$″	$2\frac{5}{16}$″	$1\frac{7}{8}$″	$1\frac{13}{16}$″	$1\frac{1}{2}$″	$1\frac{1}{8}$″
Pitch of Grooving (55°)	3″	2″	2″	1″	1″	1″	1″ (35°)



GRAPH A



GRAPH B

Mr. Gunn (in the Chair) said that the author apparently did not account for the fact of reabsorption and as Mr. Ashe had stated that the set opening was taken as 75 per cent of the calculated opening, he wondered if this allowance was helping to overcome the effect of reabsorption.

Mr. Ashe said that this allowance was used to make up for reabsorption and like assumptions made in Australia, this allowance was found at Umfolosi to be quite effective.

He had called his method a simplified one because while all the things mentioned by Dr. Douwes Dekker should be taken into account when calculating mill settings, when the hydraulics lifted, the mill settings worked out would probably be a few decimals of an inch out.

Dr. Douwes Dekker said Mr. Ashe had given a method for calculating mill setting which was different from that used by the S.M.R.I. in the Mutual Milling Control Project. Of course every engineer was entitled to use any method he thought suitable and which he thought gave the best results. Mr. Ashe claimed his was a simplified method but he had not shown which were the simplifications used to arrive at his method.

On looking at the various figures given, it was apparent that the author assumed that the volume of the cane and the volume of the bagasse could be calculated from the percentage of sucrose, fibre and water. Dr. Douwes Dekker said he could not agree with this method.

In the first place the water in the cane and that in the bagasse was not always present in the same way. Some of the water was attached to the fibre as so-called Brix-free water and apparently we could not assume that volume of the Brix-free water attached to the fibre was of the same order as the free water. When the specific gravity of fibre in an organic liquid was determined, we found that it was about 1.3. When this fibre absorbed moisture of a specific gravity of 1.0, one would expect its specific gravity to be lowered. On the contrary, the specific gravity increased and from this fact we could only assume that the water added was absorbed in some way, such as the small molecules of water becoming so attached to the fibre that it did not increase the volume. Thus a calculation of the volume of cane or of bagasse passing through a mill, made by assuming that these substances consisted simply of sucrose, fibre and water was, for this reason, difficult to justify.

Moreover, there was not only sucrose in the cane, there was Brix in the cane and its amount could be very different from the amount of sucrose in the cane. The sucrose was quoted as having a specific gravity of 1.55 but this did not exactly apply to that of the Brix. This was one of the simplifications used by the author for which there was no justification.

Another point was that the reabsorption problem was not taken into account, although it had been referred to. It was not correct to say that 75% was one of the assumptions used in Australia but of which we were not sure. There was no doubt about the fact of reabsorption. When we calculate the volume of cane or bagasse going through the ascribed volume from its constituents, as compared with what actually occurred, a big difference was found from which we must conclude that more material was passed through the opening of the mill than the space available was calculated to accommodate. This meant that either the speed of the juice alone, or that of the fibre plus the juice, was larger than the circumferential speed of the roller.

The two things mentioned should be remembered when calculating mill settings.

He pointed out also that while the Brix was a measure of soluble solids, particles of fibre in the juice should also be allowed for, and added to the Brix.

Mr. van Hengel said the author had stated that all the discrepancies due to reabsorption were accounted for in the allowance of 75%, but more than 75% allowance should be made because when the setting of a mill was worked out we knew that the set opening was going to be smaller than the work opening because of the lift of the top roller. The author had used two figures in which the discharge opening was going to be 0.72 inch and the feed opening 1.08 inches. If we do not forget that there is reabsorption Mr. Ashe's calculation of the density of bagasse as 72 lbs. per cubic foot was similar to that of Noel Deerr and the S.M.R.I. normally took 75 lbs. for all bagasses and so the 72 lb. figure was acceptable.

If the mill settings are worked out according to the S.M.R.I. formula, the discharge work opening will be found to be 0.69 inch. and the feed work opening 1.5 x 0.69=1.04 inch. (using for a moment the same ratio 1:5). These are figures in which reabsorption is taken into account and which, in fact, differ little from the 0.72 inch. and 1.08 inch. mentioned by the author.

However, the settings of a mill are normally considerably narrower than calculated for the work-openings as a constant lift of the top roller of approximately 0.25 inch should be maintained. For this reason 0.2 inch should be subtracted from both discharge- and feed-openings, bringing them to 0.49 inch and 0.84 inch respectively (ratio 1:7). Now it is not customary to apply the mill ratio to the set-openings as was done by the author, as the set-openings have no real practical meaning with respect to milling. If the same procedure had been used in the case of the S.M.R.I. settings it may have resulted in a feed set-opening of 1.5 x 0.49=0.74 inch and in lifted position of the top-roller the ratio would have been $\frac{0.74 + 0.20}{0.49 + 0.20} = 1.36$, extraordinarily low indeed.

Obviously, the factor 0.75 is too small to take the lift into account as well and, therefore, a mill set according to the method propagated by the author cannot work well. Of course, it can be reasoned that the discharge opening could be pulled in until sufficient lift occurs, but that would change the mill ratio to a large extent, and the primary goal, i.e. to predetermine the optimum position of the rollers, has not been achieved.

Mr. Ashe pointed out that no two factories could apply the same method, as variations would depend upon the way the mills were fed.

With a pressure feeder one had a different set of circumstances as compared with when no forced feeding was used.

Once the mills were set it was necessary to carry out regular observations and laboratory tests on each mill. Such tests would show which mills did not measure up to the standard required and needed further adjustment.

Mr. Kramer said that after concentrating on mill settings for many years he had found the formulae used by the S.M.R.I. gave best results.

Mr. Gunn said that with a more or less identical pressure fed mill at Tongaat with 20% more fibre but the same crushing rate the setting of the discharge roller differed by almost 100% from that used by Mr. Ashe and amounted to 0.43 inches. The peripheral speed of the mill was much slower and this would account for some of the difference.