A GUIDE TO THE MUTUAL MILLING CONTROL PROJECT

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Summary

The publication of this bulletin initiates the most comprehensive survey of sugar milling statistics that has been attempted in South Africa. Its purpose is to familiarize participating factories with the procedure to be adopted in this project. The underlying principle is to obtain a maximum amount of useful information with a minimum of additional labour from the factories by the most economical means. The final results should benefit the sugar industry as a whole.

Introduction

The S.M.R.I., acting on a request made by the Board of Control for an investigation into the performance of milling tandems, has developed a method for a statistical analysis of the factors which determine milling efficiency. This is the "Mutual Milling Control Project". The purpose of this bulletin is to provide the staff of sugar factories with a comprehensive explanation of the object and scope of the M.M.C.P. and to describe how the S.M.R.I., in co-operation with the technical staff of factories, will be able to compile data from practical milling observations.

We would like to stress that this is a mutual research project and, as such, will depend for its success largely on enthusiastic co-operation between the staff of sugar factories and the staff of the S.M.R.I.

Choice of Approach

The Mutual Milling Control Project was chosen as a method of conducting milling research in preference to other possible methods because it could be carried out at relatively low costs without burdening the mills with considerable extra work or interfering inadmissably with normal milling operations. Moreover, it is known that this method has been applied successfully in other countries.

It was realized, of course, that a more direct method of conducting milling research is possible if either a specially constructed pilot mill were available, or a complete commercial tandem were put at the disposal of the research team but, after careful deliberations, the Mutual Milling Control Project was chosen as being most suitable for present South African conditions.

Aim and Scope of the M.M.C.P.

The purpose of the M.M.C.P. is to gather information on milling variables from a number of mills so that, after statistical analysis, the information may be of mutual benefit in facilitating a more general approach to problems in milling control. In other words, we hope to get down to specific figures for each mill, by taking into account all variables such as feed rate, fibre in bagasse, mill lift, etc. This will enable us to correlate the data in terms which are independent of process variables. We would then have the means for optimising the controlled variables and, furthermore, for pin pointing the causes of poor performance due to say, mill slip, incorrect mill settings, etc. The value of the results could moreover be enhanced if we succeeded in encouraging the participation of one or more overseas factories in the project.

The object of the M.M.C.P. may be more clearly understood by the following example:

Consider the formula

$$K = \frac{167.Mc.Fc}{N.D.L.Fb} \quad \text{(see nomenclature below)}$$

by means of which, local mill settings are calculated. Subjecting this formula to dimensional analysis, we find that—

$$\text{length} = \frac{(\text{mass})\,(\text{time})^{-1}}{(\text{time})^{-1}\,(\text{length})^2}$$

which is dimensionally incorrect. Obviously, a density term must be incorporated, if the formula is to be dimensionally balanced. This "density" is the pounds of fibre per cubic foot of escribed roller volume and is at present incorporated in the constant which has been adapted from overseas statistics.

What has this to do with the M.M.C.P.? By collecting data on the process variables, i.e. pounds fibre and cubic foot of escribed roller volume, expressing them as a specific fibre index, and choosing the optimum value for peak performance, we hope to arrive at a more general formula for mill settings.

The above is just one example, but there are numerous other correlations which could be found by means of the M.M.C.P. Thus our knowledge of the fundamentals of sugar milling will be substantially increased.

Organization of the M.M.C.P.

When the factories are in a position to submit data for the M.M.C.P., data sheets will be supplied by the S.M.R.I., for the purpose of tabulating mill measurements and laboratory observations. These should be completed at the end of each week and submitted as soon as possible to the S.M.R.I. The Institute, in turn, will furnish each factory with a complete summary of all data submitted. This will be conducted along the same lines as for the weekly and monthly reports which are at present issued by the S.M.R.I.

When sufficient information has been accumulated, the S.M.R.I. will carry out a statistical analysis which we hope will evaluate the individual effect of each milling variable on performance. The observations required for this purpose are summarised on the sample data sheet below, and the methods of analysis and measurement are described in the following section.

The conclusions reached by the S.M.R.I. analysis will be made available to all factories.

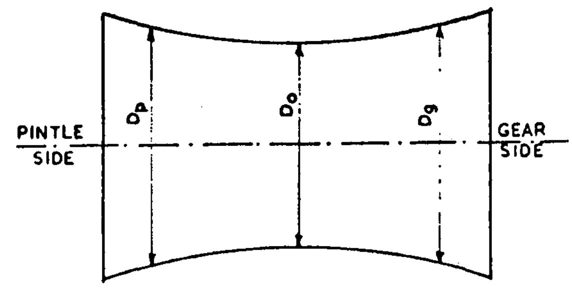

FIG.1.

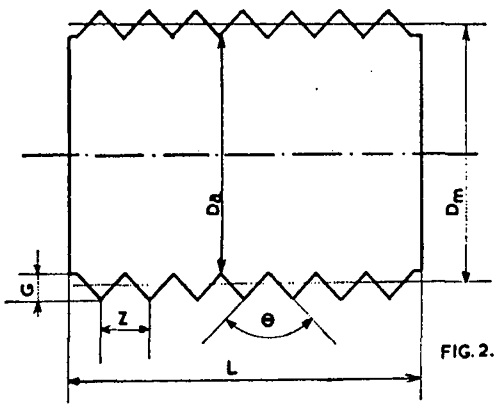

FIG. 2.

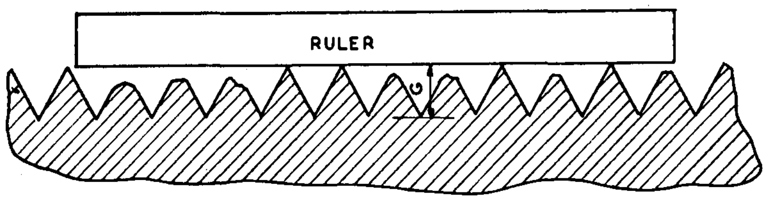

FIG.3.

Nomenclature

(i) Laboratory and Production Data

- B = brix % cane, bagasse or juice
- E = extraction
- F = fibre % cane or bagasse
- I = fibre index, lbs. fibre/cu. ft. escribed volume
- J = juice purity
- M = average mass flow rate of total expressed juice, fibre, or bagasse from a unit, ton/actual crushing period
- S = sucrose % cane, juice or bagasse
- W = moisture % cane or bagasse

Subscripts

- b = bagasse
- c = cane
- f = fibre
- h = hydration (water)
- j = juice
- m = mixed (juice)
- w = imbibition water

0, 1, 2, 3, ... z = crusher (2 roll), 1st (primary), 2nd (secondary), 3rd, . . . last, 3-roll unit.

(ii) Mill Measurements

- A = area hydraulic piston, sq. in.
- D = diameter roller, in. (see figs. 1 and 2)
- Dg = diamter measured in fifth groove from gear end, in.
- Dp = diameter measured in fifth groove from pintle end, in.
- E = distance (in grooves) between feeder and top roller, in.
- G = depth of roller groove, in.
- H = top roller lift, in.
- K = work opening, in.
- L = length of roller, in.
- N = rotary speed of roller, r.p.m.
- P = hydraulic pressure, p.s.i.g.
- Ps = specific top roller pressure, tons/sq. ft. projected roller area
- R = load on top roller, ton
- Rs = specific load on top roller, ton/ft.
- S = set opening, in.
- T = distance between centres of top and feed/discharge (subscripts f/d), in.
- Vm = circumferential speed of roller at mean diameter (Dm), ft./min.
- Z = pitch of roller groove, in.
- θ = angle of roller groove, degrees
- 1 ton = 2,000 lb.

Subscripts

- a = average (diameter)
- d = discharge side
- e = entry (refers to feeder roller)
- f = feed side
- g = gear end
- i = indicated (lift)
- m = mean (diameter)
- o = at centre of roller (diameter)
- p = pintle end
- s = specific (pressure)
- t = top (roller)
- v = true average (lift)

1, 2, 3 . . . z = 1st, 2nd, 3rd . . . last, 3-roll unit

Laboratory Observations

The data required from the laboratory may, with few exceptions, be taken directly from the results normally published in the weekly milling reports. There is no necessity to elaborate on the latter since the data required is specified in the sample data sheet below. The following additional determinations will be necessary:

(i) *Fibre % First Mill Bagasse*

In order to reduce extra work to a minimum, fibre % first mill bagasse (Fb_1) may be determined simply through a knowledge of the weight of the mixed juice (Mj_m) and the brixes of the primary, secondary and mixed juices (Bj_1, Bj_2, Bj_m).

The primary and secondary juices should be sampled continuously and analysed at the same frequency as the mixed juice. The juice may be sampled continuously from the gutters by means of a reciprocating scoop, covered by a sieve, and actuated through a chain connected to an eccentric pin on the roller pintle. Similar devices are already installed on some mills.

It should be carefully noted that primary juice refers to all undiluted expressed juice. If a two-roll crusher and three-roll mill precede the first imbibition stage, then both the latter juices constitute the primary juice.

Calculation:

By mass balance:

$$Mj_m = Mj_1 + Mj_2$$
$$= Mj_1 + (Mj_m - Mj_1)$$

Then $Mj_m.Bj_m = Mj_1.Bj_1 + (Mj_m - Mj_1)\ Bj_2$

$$\therefore Mj_1 = Mj_m \frac{(Bj_m - Bj_2)}{(Bj_1 - Bj_2)} \quad \ldots \quad (1)$$

Weight first mill bagasse—

$$Mb_1 = Mc - Mj_m \frac{(Bj_m - Bj_2)}{(Bj_1 - Bj_2)} \quad \ldots \quad (2)$$

In unit time:

Weight first mill fibre = weight fibre in cane

$$\text{Weight fibre in cane} = \frac{Mc.Fc}{100}$$

$\therefore$ Fibre % 1st mill bagasse—

$$Fb_1 = \frac{Mc.Fc}{Mc - Mj_m \frac{(Bj_m - Bj_2)}{(Bj_1 - Bj_2)}} \quad \ldots \quad (3)$$

Note.—The fibre, Fb_1, should be calculated as accurately as possible by obtaining a weekly "weighted average" which will allow for the fact that the daily brixes involved apply to different weights of juice. The following procedure should be followed:

Calculate Mb_1 by formula (2) at the end of each day using the numerical average of the recorded brixes for that day. At the end of each week, calculate Fb_1 by formula (3) using the total fibre weight and the sum of the daily 1st mill bagasse weights for the week.

(ii) *Primary Juice Extraction*

The primary juice extraction (Ej_1) is a useful figure for comparing the performance of first mills with overall extraction. The calcuation requires no additional analyses.

Calculation:

$$Ej_1 = \frac{Mj_1}{(Mc - 1.3\ Mf)} \quad \ldots \quad (4)$$

(iii) *General*

The remainder of the information required from laboratories will be found on the data sheet below.

Any difficulties experienced in sampling, etc., should be referred to the S.M.R.I. immediately.

Mill Measurements

The following data will be required from the first and last three-roll units of milling tandems. The investigation has been limited to the first and last three-roll units since the cost and additional work involved do not warrant extending the observations to include intermediate mills. The average weekly measurements should be tabulated on the data sheets.

(i) *Roller Dimensions*

In order to calculate the escribed volume between rollers of the first and last three-roll units, the following method may be adopted for measuring the average diameters (Da) of the rollers:

The diameter in the central groove (Do) and also the diameters in the fifth grooves from both gear and pintle ends (Dg, Dp) are measured, as in fig. 1. From these three diameters, the average diameter (Da) may be calculated.

Calculation:

$$Da = \frac{Dp + Dg + 2Do}{4} \quad \ldots \quad (5)$$

The mean roller diameter (Dm) shown in fig. 2 may then be found after measuring the groove depth by placing a steel ruler across the roller grooves and measuring the depth by means of callipers, as shown in fig. 3.

Calculation:

$$Dm = Da + G \quad \ldots \quad (6)$$

The angle of the roller groove (θ) may be calculated from the groove depth (G) and the pitch (Z).

Calculation:

$$\mathrm{Tan}(\theta/2) = Z/(2G) \quad \ldots \quad (7)$$

Note 1.—An instrument, for the purpose of measuring roller diameters, will be supplied with operating instructions to each factory.

Note 2.—The effect of chevron and messchaert grooves will not be investigated in the initial stages of this project.

(ii) *Set Openings*

The feed and discharge set openings (Sf, Sd), for the first and last three-roller units may both be calculated in the same manner. For example, the discharge set opening of the last mill (Sd_z) may be calculated from the mean diameters of the discharge and top rollers (Dmd_z, Dmt_z) and the distance between the centres of the rollers (Td_z) shown in fig. 4.

Calculation:

$$Sd_z = Td_z - \frac{(Dmd_z + Dmt_z)}{2} \quad \ldots \quad (8)$$

The feeder roll opening (Se) may be calculated on similar lines, but in this case the distance (in grooves) between the feeder roller and top roller (E) should be measured with callipers and the mean distance calculated using the known groove depths (Gt, Ge)

Calculation:

$$Se = E - \frac{(Gt + Ge)}{2} \quad \ldots \quad (9)$$

(iii) *True Average Roller Lift*

The average indicated top roller lift (Hi) for the weekly run may be calculated from power consumption of the lift integrators. To this end the precautions in section (V) should be carefully followed.

Calculation:

$$Hi = \frac{\text{K.W.H. consumed x 1000 x 0.05}}{\text{40 x actual crushing hours}} + 0.025$$

$$= \frac{\text{1.25 x K.W.H.}}{\text{act. crush. hr.}} + 0.025 \quad \ldots \quad (10)$$

Note.—The above formula applies only to integrators fitted with 40 watt indicating globes, each of which is illuminated by a 0.05 in. increase in lift.

The true everage lift (H) may be calculated from the indicated average lift by simple trigonometry of triangle ABE in fig. 5.

Calculation:

$$Hv = 0.77\ Hi \quad \ldots \quad (11)$$

$$\text{Also } Hm = \frac{Hvp + Hvg}{2} \quad \ldots \quad (12)$$

Note.—Since the lift integrator performs a setpwise integration its accuracy is limited unless each step is infinitely small. However, this type of graphical integration is commonly used for the evaluation of random integrals and is sufficiently accurate for practical applications. Furthermore, it is apparent from graphical analysis that, provided a correction of 0.025 is added to the lift formula as in equation (10), small errors which occur are compensated and not accumulated in this case. This applies of course, only to a freely moving roller.

Hence the accuracy of the integrator is of the order of the free play in the micro switches and the actuating mechanism.

(iv) *Work Openings*

The work openings (Kf, Kd) for feed and discharge sides of the first and last three-roll units may be found from the sum of the set openings (S) and true average lift (Hv) for the weekly run.

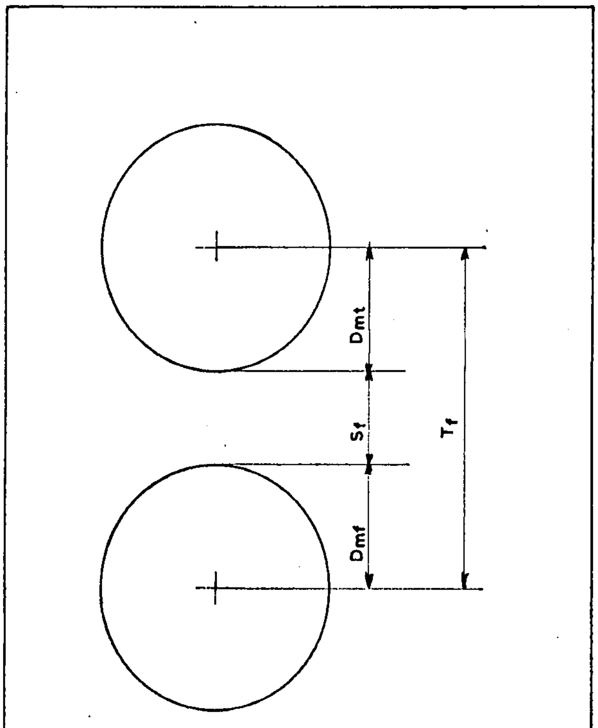

FIG. 4.

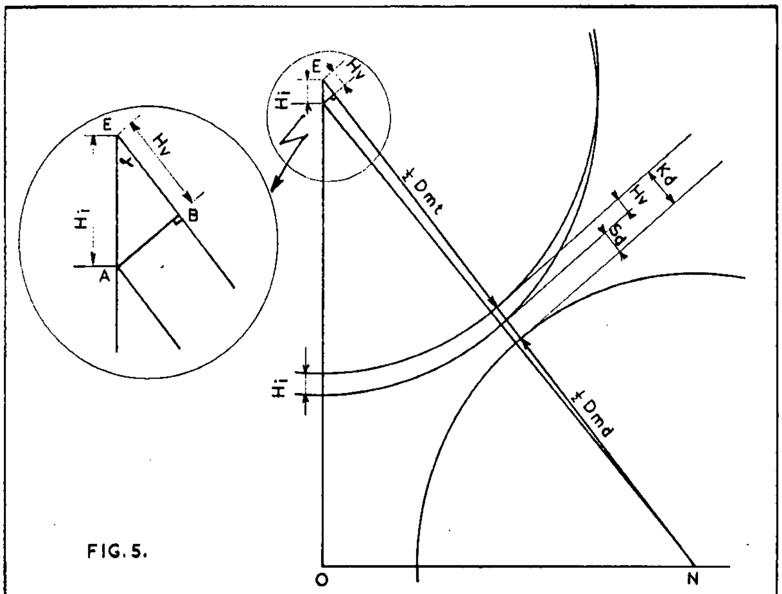

FIG. 5.

Calculation:

$$K = S + Hv \quad \ldots \quad (13)$$

$$\text{Also } Km = S + Hm \quad \ldots \quad (14)$$

(v) *Use of the Lift Integrator*

The operation of the lift integrator is extremely simple and has been fully described in the S.M.R.I. Quarterly Bulletin No. 16, also S.A.S.J., 44, 10, (1960). However, the following should be carefully observed:

(*a*) At the beginning of a weekly run, the time should be noted, the K.W.H. meter read to the nearest 0.01 K.W.H. and the globes should be tested by depressing the test switch. The latter operation will not be recorded, since the test switch circuit is connected to the open circuit terminals of the micro switches and is consequently independent of the meter circuit.

(*b*) During a weekly run, the duration of mill stoppages should be noted and (unless no lift is indicated) the integrator should be switched off as soon as the mill stops. The integrator should be immediately switched on when the mill starts.

It is important that the globes be tested regularly and replaced immediately if faulty. Spare globes will be supplied with the integrator. If failure of a globe is not noticed on occurrence, a note to this effect should be made in the report to the S.M.R.I.

The instrument requires virtually no maintenance, but the guides of the sliding follower below the integrating switch box should be lubricated occasionally with a multi-purpose grease. The sealed rollers should be cleaned if they become clogged with bagacillo. Should they seize due to internal corrosion, they will cause wear on the mill flange unless replaced. Spare rollers will be supplied with the integrator.

A small amount of wear will occur over several months' operation. Hence the follower should occasionally be zeroed against the top roller flange in the rest position and the plunger of the first micro switch. This operation is described in the S.M.R.I. Quarterly Bulletin No. 16.

(*c*) At the end of a weekly run, the time and K.W.H. should be noted and the globes checked as in (*a*).

(vi) *Circumferential Speed of Roller*

The speed of the top roller (N) may be found by means of a tip counter actuated by an eccentric pin mounted on the pintle or other suitable position. Counters will be supplied with the integrators.

The actual operating time and total revolutions should be noted at the end of a weekly run and the r.p.m. calculated.

Calculation:

$$Vm = Dm.N/12$$

Note.—Since the rev. counter operates continuously, there may be some doubt as to the applicability of the recorded reading when the rollers are running empty, due either to delays in cane delivery or to mill washing operations. In the former case, we suggest that the increase in recorded revs. will be negligible in comparison with the total for a weekly run. Consider for example a 3 r.p.m. roller, which during a week's operation, would rotate through about 26,000 revolutions. To accumulate an error of 1% of the total revs. due to "idling" would require more than $1\frac{1}{2}$ hours delay in cane delivery, etc. over the week. But since the actual idling speed is normally reduced to about 1 r.p.m., it would in fact take $4\frac{1}{2}$ hours for a 1% error.

In the latter case, we suggest that when roller idling is anticipated, the rev. counter lever should be rotated out of the path of the actuating pin on the pintle and replaced as soon as normal operations are resumed. This operation is facilitated by a locking screw on the lever of the rev. counter and the lever may be reset by drilling a small hole in the shaft to locate the locking screw.

(vii) *Hydraulic Pressure*

An average weekly pressure (Pg, Pp) of the hydraulics on both sides of the first and last three roll units should be noted. The area (Ag, Ap) of each hydraulic piston should be determined. Total load (R) on the top roller may then be calculated.

Calculation:

$$R = \frac{(Pg.Ag + Pp.Ap)}{2{,}000} \quad \ldots \quad (15)$$

$$\text{Also } Rs = 12R/L \quad \ldots \quad (16)$$

$$\text{and } Ps = \frac{144R}{Dmt,\, L} \quad \ldots \quad (17)$$

(viii) *General*

It is essential that each mill should adopt the method described above as a standard, if the final calculations are to be comparable. Should difficulties arise, due to peculiarities in a mill housing, etc., the S.M.R.I. should be advised immediately.

Conclusion

The above information will serve as an introductory guide to the M.M.C.P. However, when the factories reach the stage where they are able to carry out the required observations, we anticipate that some small difficulties may arise. The members of the S.M.R.I. staff concerned in this project will be glad to give all possible assistance to the factories.

SUGAR MILLING RESEARCH INSTITUTE

MUTUAL MILLING CONTROL PROJECT DATA SHEET

Note: These forms should be filled in and forwarded to the Director, Sugar Milling Research Institute, University Private Bag, King George V Avenue, Durban, as soon as possible. Forms which have not arrived by the Second Monday morning following the weekly period, cannot be taken into consideration.

Week Ending..............................

Factory.............................. Weekly Report No..............................

	Week	*To Date*
Mc (Tons cane)	27,580	394,431
Mw (Tons imbibition water)	9,973	148,898
Mjm (Tons mixed juice)	28,360	409,489
Mbz (Tons final bagasse)	9,193	133,840
Mb_1 (Tons first mill bagasse)	14,775	220,513
Mf (Tons fibre)	4,137	59,559
$\frac{Mc \times Bc}{100}$ (Tons brix in cane)	4,315	61,972
$\frac{Mbz \times Bbz}{100}$ (Tons brix in final bagasse)	345	4,550
$\frac{Mc \times Sc}{100}$ (Tons sucrose in cane)	3,668	52,061
$\frac{Mjm \times Sjm}{100}$ (Tons sucrose in mixed juice)	92.0	92.3

	1st Unit	*Last UNIT*
Lt	84	84
Gf	1.75	0.91
Gt	1.78	0.95
Gd	2.00	0.94
Dmf	40.48	40.89
Dmt	41.20	41.69
Dmd	42.00	42.08
Sf	2.76	1.41
Sd	1.13	0.71
Se	8.4	4.5
Kwh p W.	24.08	17.36
Kwh g W.	27.44	26.32
Kwh p T.D.	366.99	399.16
Kwh g T.D.	295.87	449.65
Hvp	0.18	0.14
Hvg	0.21	0.20
Hvm	0.20	0.17
Kf	2.96	1.58
Kd	1.33	0.88
Mill Ratio	2.23	1.80

	1st UNIT	*Last UNIT*
Pp	3,000	4,000
Pg	3,500	4,000
R	364	448
Rs	52	64
Ps	15.2	18.4
Nt W.	32,641	29,380
Nt T.D.	00,381	70,719
Act. crushing hours W.	140.00	
T.D.	2,014.55	

REMARKS

1. Discharge roller on first mill replaced.

SUGAR MILLING RESEARCH INSTITUTE

MUTUAL MILLING CONTROL PROJECT — CALCULATION SHEET

Week Ending.. Factory..

Corresponding to Weekly Report No..............................

Note: Figures appearing in the squares should be transposed to the Weekly Data Sheets. These Calculation Sheets should be retained for reference purposes. In cases where data of two milling tandems are available, separate Calculation Sheets should be completed and separate Data Sheets submitted to the S.M.R.I.

	1st UNIT			Last UNIT		
	f	t	d	f	t	d
Lt		[84]			[84]	
Do X 2	38.70 2	39.40 2	40.00 2	39.95 2	40.70 2	41.12 2
2 Do Dp + Dg	77.40 38.79 38.74	78.80 39.43 39.48	80.00 40.00 40.00	79.90 39.99 40.01	81.40 40.77 40.77	82.24 41.14 41.17
2Do+Dp+Dg ÷ 4	154.93 4	157.71 4	160.00 4	159.90 4	162.94 4	164.55 4
Da + G	38.73 [1.75]	39.42 [1.78]	40.00 [2.00]	39.98 [0.91]	40.74 [0.95]	41.14 [0.94]
Dm + Dmt	[40.48] 41.20	[41.20] ←→	[42.00] 41.20	[40.89] 41.69	[41.69] ←→	[42.08] 41.69
÷ 2	81.68 2		83.20 2	82.58 2		83.77 2
Dmf+Dmt 2	40.84			41.29		
Dmd+Dmt 2			41.60			41.88
Tf −	43.60 40.84			42.70 41.29		
Sf	[2.76]			[1.41]		
Td −			42.73 41.60			42.59 41.88
Sd			[1.13]			[0.71]

	1st UNIT		Last UNIT	
	p	g	p	g
Kwh total −Kwh previous	[396.99] 372.91	[295.07] 268.43	[399.16] 381.80	[449.65] 423.33
Kwh week X 1.25	[24.08] 1.25	[27.44] 1.25	[17.36] 1.25	[26.32] 1.25
÷ act. cr. hours	30.10 [140.00]	34.30 [140.00]	21.70 [140.00]	32.90 [140.00]
+ 0.025	0.215 0.025	0.245 0.025	0.155 0.025	0.235 0.025
Hi X 0.77	0.230 0.77	0.270 0.77	0.810 0.77	0.260 0.77
Hv +	[0.18] 0.21	[0.21] ←	[0.14] 0.20	[0.20] ←
÷ 2	0.39 2		0.34 2	
Hvm + Sf	[0.20] 2.76	↓	[0.17] 1.41	↓
Kf Sd +	[2.96]	0.20 1.13	[1.58]	0.17 0.71
Kd ÷	1.33	[1.33] ←	0.88	[0.88] ←
Mill Ratio	[2.23]		[1.80]	

	1st UNIT	Last UNIT
Nt total Nt previous total	[00,381] 67,740	[70,719] 41,339
Nt week	[32,641]	[29,380]
Act. crushing hours total Act. crushing hours previous total	[2,014.55] 1,874.55	
Act. crushing hours week	[140.00]	
Se (feeder opening)	[8.4]	[4.5]

	1st UNIT		Last UNIT	
	p	g	p	g
P X A	[3,000] 112	[3,500] 112	[4,000] 112	[4,000] 112
PxA + PgAg	336,000 392,000	392,000 ←	448,000 448,000	448,000 ←
PpAp+PgAg ÷ 2,000	728,000 2,000		896,000 2,000	
R ÷ L/12	[364] 7		[448] 7	
Rs ÷ Dmt/12	[52] 3.43		[64] 3.47	
Ps	[15.2]		[18.4]	

Mr. J. Cargill asked when the project would start and Mr. van Hengel thought this would be at the middle of May, but probably more could be expected from the scheme in the second, rather than in the first, year.

Mr. J. R. Gunn asked if the formula for fibre per cent first mill bagasse was accurate when the cane was in a muddy condition.

Mr. van Hengel replied in the affirmative. The mud would go into the juice and be weighed as such and the calculated bagasse weight should be correct as far as possible, and it was from this that the fibre was calculated. The formula was mathematically correct. If the brix of the juice was taken to two decimal places one could be confident of one's calculation of how much primary juice was in the mixed juice, and this, subtracted from the cane weight, would enable one to calculate the first mill bagasse weight.

Mr. J. R. Gunn said that while some factories used "wooly" top rollers, others did not, and the grooving, varying between factories, also affected the amount of "wooliness". He asked how the Sugar Milling Research Institute was going to evaluate the effect of the dirty top roller?

Mr. van Hengel thought the Australian method should be followed. This assumed that when a roller was wooly, the whole groove was filled except the bottom ¼ inch and it was accepted that under compression this opening was left free.

Mr. J. W. Main said he was a keen supporter of such a system of Mutual Mill Control. He had experienced such a system in operation in India. This had been introduced by Mr. Noel Deer and the improvement in extraction at certain factories was astounding, following the application of the system.