

SUGAR MILLING IN NATAL

SOME OBSERVATIONS ON THE VARIABLES CONNECTED WITH MILLING

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With the object of collecting information on milling practice in Natal, a milling sub-committee of the Natal Sugar Technologists' Association issued a questionnaire to all mills. It was very comprehensive in the data asked for, and in order to make the results as truly comparative as possible, replies covered the same period for all mills, namely, the peak period of August, 1946. It is pleasing to record that seventeen mills replied to this questionnaire, and from these replies most data given here have been compiled.

Milling may be defined as "a process of extracting sucrose from cane, by means of repeated pressure expressions of a rotary nature." Without enlarging on the purely mechanical aspects of this definition, the extent of this extraction is governed by a series of variables all of which, with the exception of the natural structure of the cane raw product, can be controlled and adjusted by human agency. These variables may be listed as: (a) Capacity rating, (b) Preparation for the milling process, (c) Roll pressure application, (d) Maceration, (e) Peripheral speeds, (f) Mill settings; all of these being applied to the ideal of removing as much of the soluble solids in solution and leaving the final bagasse in as dry a state as possible. The latter condition, it may be remarked, has a greater significance in efficiency than is generally realised.

Capacity Rating.

The term "capacity" of a milling plant looms largely in the industry at the moment. Mainly due to the demands brought about by a series of war years, the mechanical side of sugar production has been called upon to increase throughput considerably. It is worthy of note that a splendid job of work was done in handling the increased tonnage while maintaining plant under most difficult conditions.

The following figures are extracted from the Annual Summary of Laboratory Reports from the Experiment Station ^{3,4,5} for the years concerned:—

	1937.	1944 (<i>peak</i>)	1945.
Total tons of cane crushed	4,301,068	5,255,032	4,549,559
Tons crushed per hour ..	78.64	86.72	87.88
Extraction per cent. ..	91.53	93.13	93.28
Moisture per cent. bagasse	52.01	50.23	50.12
Fibre per cent. cane ..	15.14	15.83	15.99
Extraction per cent. ..	91.53	93.13	93.28
Moisture per cent. bagasse	52.01	50.23	50.12
Fibre per cent. cane ..	15.14	15.83	15.99

The period has been chosen, as it embraces the gradual replacement of Uba cane by new varieties. 1944 is included because it was the peak year of production and the time factor consequently became of great importance. Drought conditions were responsible for the falling off in total tons of cane milled from 1945 onwards.

The figures are revealing in that they show not only a considerable increase in crushing rate (11.7 per cent.) but also an increase in extraction and reduction in moisture, against a positive rise in fibre. Yet despite this rate increase, the crushing seasons had to be lengthened to cope with the rise in cane output; in some cases to inordinate lengths.

This general improvement revealed, leads to the conclusion that perhaps the new cane varieties are an important factor and that mills generally have been able to increase their mechanical efficiency despite capacity increase. This improved efficiency probably would have been greater, had it not been accompanied by an increase in crushing rate.

Some means of assessing the capacity of a milling plant has to be considered, however. It all depends on what can be generally accepted as a standard of performance. A given plant can definitely increase output by increasing either speed or opening area, but at the cost of increased efficiency. Again, an extra mill enables output to be increased without necessarily losing efficiency, due to the fact that the added expressions and extra maceration effect compensate for the necessity of having to increase either speed or opening areas.

Thus too many variables are involved in assessing capacities by any standard formula (if one does exist), and it is feared that this form of comparison will continue to remain somewhat controversial. Analyses of leading overseas formulæ give widely divergent results, and in attempting to apply them to Natal conditions they produce figures that are entirely misleading. In view of this, those that are interested or may require to assess a particular circumstance, may refer to the Appendix, wherein a formula has been evolved, which can be considered to give generally fair results for Natal conditions. Beyond this, capacity formulæ are entirely empirical.

Preparation for Milling.

Preparation involves those methods used for reducing the cane structure to a consistent mass, to-

TABLE 1.—Mechanical and other Features Governing the Variables in Milling.
(Figures are for August, 1946.)

Name of Mill.	Mill No.	A	B	C	D	E	F	G	H	J	K
		Extraction per cent. for August, 1946	Drainage grooving in feed rolls.	Auxiliary feed appliances.	Maceration temperature °F and per cent. on cane.	Average hydraulic load on mills, tons per square inch per lin. length.	Hydraulic load on last mill, tons per sq. inch, per 1 inch length.	Last mill, how driven.	Average peripheral speed of mills, feet per min.	Average speed of intercarriers, feet per min.	Type of inter-carrier.
Umzimkulu	1	91.80	Yes	Rammers	100°/35	4.75	5.5	Single	14.90	14.75	Rake
Esperanza... ..	3	94.42	„ 4m.	Nil	100°/37.6	3.91	Toggles	Coupled	19.30	17.25	Apron
Renishaw... ..	4	94.10	„	Feed rolls	110°/31	3.52	4.33	Coupled	16.20	17.56	Apron
Natal Estates	6	94.50	„	„	135°/40	3.15	3.55+	Single	34.55	35.95	Apron
Verulam	7	94.71	„	„	Cold/28.7	Toggles	Toggles	Single	19.30	—	Apron
Tongaat A	8	94.17	„	„	Cold/27	4.54	4.80	Single	21.30	19.00	Apron
Tongaat B	8	94.39	„	„	Cold/30	4.36	5.12	Single	20.20	19.00	Apron
Chakas Kraal	9	92.10	„	Rammers	Cold/37	Toggles	3.75	Single	19.80	23.80	Rake
Melville	10	91.80	„	„	Cold/29	3.00	3.06	Triple	20.20	35.20	Rake
Gledhow	11	92.60	„	„	Cold/34	5.45	5.75	Coupled	22.60	24.00	Apron
Doornkop... ..	12	93.50	„	„	140°/37	3.52	3.70	Coupled	19.80	21.78	Both
New Guelderland	13	92.80	„	Feed rolls	110°/33	2.36	2.08	Coupled	19.10	19.00	Apron
Darnall A... ..	14	91.40	„	„ (last m.)	Cold/39	4.25	5.92	Single	27.00	31.90	Apron
Darnall B... ..	14	91.40	„	„ „	Cold/39	5.13	5.63	Triple	19.75	17.00	Apron
Amatikulu	15	92.58	„ 2 m.	„ (2 m.)	113°/41.5	5.50	5.75	Single	27.50	26.66	Apron
Felixton	16	93.50	„	Feed rolls	Cold/33	3.79	3.73	Triple	26.70	26.00	Apron
Empangeni	17	93.21	„ 4 m.	Nil	90°/34.7	3.62	5.70	Single	29.70	27.20	Apron
Entumeni... ..	18	93.40	„	Rammers	Cold/40	2.59	3.28	Single	24.80	—	Apron
Umfolosi	19	93.20	„	Feed rolls	160°/31	3.93	Toggles	Coupled	17.80	17.00	Apron
Indian mill	20	94.66	—	—	22.9	3.99	4.00	—	—	—	—
Indian mill	21	95.46	—	—	22.5	3.99	4.00	—	—	—	—

gether with volumetric reduction as far as is possible, in order to lessen the work done by the subsequent milling. The standard plant for doing this consists of combinations of knives, crushers and shredders, with the first mill sometimes being considered as a preparatory agent. Indeed, it can be asserted that if no maceration is used before this unit, then technically it comes within the preparatory stage.

Cane knives.—With one exception, all mills use them, and one has two sets installed. Average power consumed works out at 2.54 h.p. per ton of cane crushed, at an average operating distance from the carrier face of 3.7 inches. Those mills showing high operating distances due to lack of power have not been included in these averages. Total average revolutions per minute work out at 600, within the range 500/700 r.p.m.

The crushing plant should be treated as a whole, the main desirability being the extent of volumetric reduction attained. It is obvious that the greater the extent of reduction thus reached, including fibre disintegration, the closer can be the settings of the following mills and the greater the subsequent extraction efficiency. This point will be dealt with in more detail under mill settings.

Opinions differ as to what can be expected in the way of volumetric reduction by crusher installations. As a guide, it should be expected of a single crusher to give 50 per cent. and a double crusher about 60 per cent. (if not more). A series of tests taken by the writer on a double-crusher plant gave an average reduction of 60 per cent. after the first mill.

Technically, shredding gives no volumetric reduction, but it cannot be denied that the use of shredders so pulverises the fibre to a consistent mass, that the work of further reduction in the milling train is considerably lessened, leaving to them the work of repeated pressure-squeezing only. From the observed results, it is significant that nearly all mills attaining over 94 per cent. extraction have single crushers followed by a shredder.

Another point of importance in crushing plant is the diametrical size of the rollers, as compared with those used in the milling train. It is known that the larger the diameter, the less the angle of slip between cane and feed entrance. This applies more particularly to crusher installations, as these rolls have to grip the cane in a much coarser state of preparation. While crusher rolls are generally longer than mill rolls in the train, very few installations show much larger diametrical proportions. Of those having the latter, two mills in particular have crushing rates over normal capacity rating and best extractions.

Roll Pressures.

As sufficient pressure in the squeezing process cannot be met by roll weight alone, additional force must be applied by mechanical means. In general use are the hydraulic system, springs or toggles-cum-springs.

Table 1 (columns E and F) gives averages of pressure applied per inch length of roll throughout Natal, and these range from 2.36 to 5.92 tons. Giving pressure applications in this form makes comparison easier and conforms to unit pressure used in accompanying diagrams, which will be dealt with later.

To analyse these pressure applications along with results, which must be expressed mainly in terms of moisture reduction, would only lead to something inconclusive, as it by no means follows that those using the highest pressures are getting the best results. If then, in practice, as is shown in the figures given, excessive pressure loading does not give the desired results, then it is obvious that other factors have to be taken into consideration, such as loss of pressure due to unbalanced forces, too high a trash plate taking up more than its share of pressure, or even positive jamming of bearings or hydraulic rams within their containers.

Deerr² proved that bagasse cannot, by mechanical means, be compressed beyond a density of 79 lbs. per cubic foot, even though the specific density of fibre itself is 87.4 lbs. per cubic foot (specific gravity of fibre taken at 1.4, being average of Natal fibres, per tests made by Dr. Hedley for the writer). In an Appendix to this paper, it will be seen that by computation, bagasse with 45 per cent. moisture and 16 per cent. fibre in cane, has a density of 74.2 lbs. per cubic foot. As this is positive and not assumption, it follows that any pressure in excess of that needed to produce this density is only wasted in friction and other non-productive losses. The importance of bagasse densities will be appreciated more fully under mill settings. Sufficient to say now that they should form the main basis of all calculations in milling.

Table 2 (column B) shows the actual bagasse densities as worked out for each mill on its results for August, 1946; and while they collectively show an average consistency of 72.6 lbs., yet that is because the average moisture is round 50 per cent. Notable exceptions to this are mills Nos. 1 and 18 and Indian mill examples 20 and 21, which show actual densities of 74 lbs. This is proved by their respective low moistures in final bagasse of 45 per cent. Yet their unit pressure applications are by no means the highest, and some of the latter show the highest moistures.

TABLE 2.—Showing Milling Figures as given for August, 1946, from which are obtained: A—actual bagasse volumes in C.F.M. from Last Mill Discharge; B—their corresponding actual Densities in lbs. cubic foot; C—ideal Bagasse volumes at 75 lbs. density; D—actual Last Mill discharge openings in C.F.M.; E—same Mill openings as they would be set if using Bag. U = .10.

Mill No.	Tons cane per hour.	Extraction per cent.	Fibre per cent. cane.	Bagasse per cent. cane.	Moisture per cent. bagasse.	Sucrose per cent. bagasse.	A Actual bagasse volume, c.f.m. as calculated.	B Actual bagasse density, lbs. per cub. ft.	C Ideal bagasse volume at 75 lbs. cub. ft.	D Actual last mill discharge opening, c.f.m.	E Ideal mill discharge opening, c.f.m., if using Bag. U = 10
1 ..	25.00	91.81	16.00	32.33	45.26	3.85	3.64	74.0	3.59	0.88	2.50
3 ...	47.52	94.42	16.29	33.22	47.55	2.57	7.14	73.4	6.98	4.75	4.17
4 ...	41.70	94.06	15.70	33.45	49.60	2.69	6.39	73.0	6.20	4.17	4.17
6 ..	140.80	94.54	15.66	34.48	51.56	2.28	22.37	72.5	21.60	9.00	14.00
7 ..	41.49	94.71	16.46	33.70	48.15	2.30	6.36	73.2	6.22	4.25	4.15
8A ..	69.26	94.17	16.03	34.60	50.15	2.49	11.00	72.6	10.64	4.23	6.92
8B ..	66.72	94.39	14.55	30.77	48.82	2.77	9.37	73.0	9.10	1.88	6.67
9 ..	33.70	92.10	15.87	35.09	50.50	3.39	5.41	72.8	5.25	4.50	3.37
10 ..	31.80	91.75	16.07	35.93	50.65	3.46	5.25	72.4	5.07	3.40	3.18
11 ..	66.40	92.58	16.65	36.59	50.57	2.96	11.15	72.6	10.80	4.12	6.64
12 ..	28.70	93.57	15.40	31.74	46.31	3.08	4.13	73.4	4.04	1.64	2.87
13 ..	35.15	92.83	15.88	33.46	48.26	3.15	5.36	73.0	5.23	3.40	3.52
14*	122.00	91.40	16.60	38.36	52.30	3.42	20.16	72.2	19.40	8.88	12.20
15 ..	74.58	92.58	17.60	39.12	51.37	2.89	13.42	72.1	12.96	9.22	7.50
16 ..	77.36	93.57	16.31	35.52	50.47	2.53	12.61	72.8	12.21	6.12	7.74
17 ..	93.25	93.21	16.83	36.00	49.28	2.68	15.38	72.8	14.90	8.37	9.33
18 ..	15.04	93.40	15.58	31.24	45.99	3.31	2.11	74.1	2.08	m/m.	1.50
19 ..	83.95	93.17	14.46	32.32	51.52	2.90	12.49	72.5	12.05	7.95	8.39
20 ..	42.40	94.66	17.24	32.80	45.11	1.84	6.20	74.0	6.12	4.27	4.24
21 ..	43.40	95.46	16.99	32.15	45.77	1.59	6.17	74.0	6.10	3.24	4.34
20 ..	42.40	94.66	17.24	32.80	45.11	1.84	6.20	74.0	6.12	4.27	4.24

* Between two tandems.

Many attempts have been made to compute the pressure variation between feed and discharge settings in mills. The generally accepted theory is that the resultant force from top-roll pressure application acts at about 15° to the vertical. This is based on the assumption that twice the pressure is exerted on discharge bagasse roller as compared with the feed roller. A vector-force diagram, drawn to this assumption, shows that this is correct, as in Fig. 1 the dotted line set at 15° yields components of 1000 on the feed side and 2000 on the discharge. This, however, does not indicate that the ratio of feed/discharge settings is as 2 to 1.

Measurements made on worn top-roll brasses over a number of years by the writer, tend to show that the average true resultant is somewhat greater than 30° when the ratio of feed to discharge openings is in excess of 2/1. While the unworn bearing periphery of 3 inches in Fig. 1 is taken as a minimum, yet in all cases where this measurement has exceeded this figure, it has been found that the opening ratio greatly exceeds 2/1. The vector-force diagram in Fig. 1 now shows that the force components to a 29½° resultant, are as 320 on the feed side to 2000 on the discharge.

This assertion can be substantiated by (1) referring to a series of tests on bagasse compressions and

(2) analysing the state of bagasse prior to feed and discharge roll actions.

(1) *Extracted from Compression Tests on Wet Bagasse, made by Murray⁸ and Macbeth.*

Cane variety Co.281 (chosen because of high percentage crushed in Natal).

Number of tests 3

Original depth of bale 15", bagasse moist. 52%

Load on bagasse in lbs. sq. in.

Depth of bale in inches.

224 2.55

672 1.94

1,120 1.79

1,568 1.66

1,792 1.63

2,800 1.52

4,480 1.42

5,600 1.35

Weight of wet bagasse 500 grams

Weight of pressed bagasse... .. 374 grams

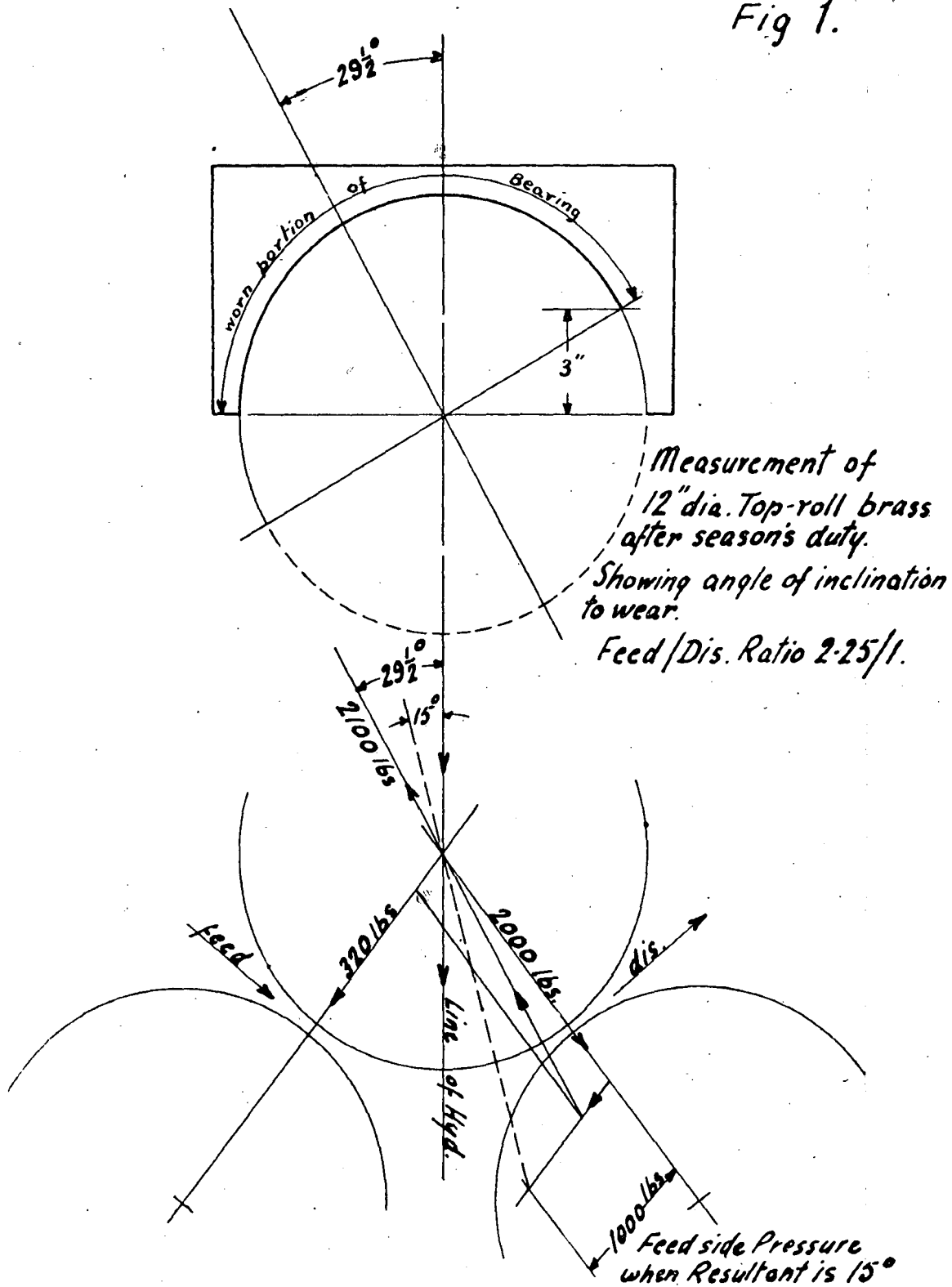
Weight of expressed juice... .. 126 grams

Moisture in pressed bagasse 35.8 per cent.

Density of pressed bagasse

(in milling) 76.4 lbs. c.f. (by the writer).

Fig 1.



Force-Vector Diagram

Setting Hydraulic Resultant at $29\frac{1}{2}^\circ$

This shows that to get a Unit Press. of 2000 lbs on Dis. Side, the Feed Press is only 320 lbs and the Resultant is 2100 lbs.

Observations to be made from the above extract are :—

(1) That a pressure of only 224 lbs. sq. in. is required to compress free bagasse from 15 inches to a depth of 2.55 inches.

(2) That to reduce the bale depth from 2.55 inches to 1.35 inches, corresponding to a feed to discharge ratio of 1.89/1, required an increase of pressure from 224 lbs. to 5,600 lbs. to give a moisture of 36 per cent.

(3) That, by computation, an approximate pressure of only 1,400 lbs. per sq. in. is needed to induce a bagasse density of 75 lbs. c.f. (in round figures) corresponding to a moisture of 45 per cent.

Deductions to be made from these observations are that the 30° resultant in mill pressure application is substantiated, and that unless radical alteration in headstock design is introduced, our mills cannot hope to attain moistures much below 45 per cent., especially when the direct pressure rises from 1,400 lbs. for 45 per cent. moisture to 5,600 lbs. for 36 per cent. moisture. High throughput demands certainly further reduce the prospects.

(2) *The state of Bagasse prior to Feed and Discharge Roll actions.*

As fibre volume is the same in both, the additional volume filling the feed opening area is wholly liquid. Being incompressible in itself, very little comparative pressure is needed to expel this liquid. There is a great difference between what may be termed inherent moisture in bagasse and that held in free suspension. Up to 55 per cent. moisture separation is relatively easy, but beyond that, the remainder being inherent in the fibre structure itself, becomes increasingly difficult to separate mechanically. Thus any mill opening larger than that set to produce bagasse at a required density, gives a disparaging drop in pressure on the feed side, until at ratios above 2.5/1 it virtually disappears altogether. The practice of permitting a continuous excessive top-roll lift while crushing, only accentuates this feed pressure drop, and transfers it all to further friction and unbalanced torque in top-roll brasses.

The influence of roll diameters on pressure application is another factor to be considered. Fig. 2 graphically illustrates the statement that as the diameter of rolls increases, so a proportionate increase in unit pressure must be applied, in order that the bagasse may be subjected to the same intensity of squeeze effect to attain a constant result. Thus, other things being equal, a 34" by 66" mill, for example, should carry a greater load per inch of length, if it is to give results equivalent to that from

a 24" by 48" mill. Increase in roll weight can be taken into consideration if desired; the maximum increase between a 24" and a 36" roll amounts to about 320 lbs. per inch of length, against a gross required increase of 1,200 lbs. This is admittedly an academic point, since in practice such excessive loading is necessary to overcome friction first, that the differences given become negligible. Were mill design to conform to practical needs, then loading to the diameter of the rolls would assume more significance.

All that has been said goes to show that if we accept the maximum rotating pressure required to produce bagasse at 45 per cent. moisture as 2,000 lbs. per sq. in., then the column of hydraulic pressures as used in our mills is somewhat excessive. Thus the fact is emphasised that a large proportion of that excess pressure is really necessary, in order to overcome the non-productive losses before the under-terminated balance can be utilised in direct roll-to-roll pressure in operation. Further, until superior mechanical means can be evolved to force bagasse into feed openings of much less than the normal 2/1 ratio, our mills must remain extremely unbalanced and rely on discharge roll action for fibre disintegration and inherent moisture expression.

As far as comparisons can be made between the various types of pressure application, while hydraulic systems predominate, excellent results are also obtained from toggles. Technically, hydraulic rams only give a constant pressure under varying degrees of lift, while spring and toggle appliances give increasing pressures. Maintenance also is heavier for hydraulics and more floor-space is taken up. They do have the advantage in that the load application can be determined by gauge reading, but beyond that there is no means of ensuring that the pressure applied is being used effectively in bagasse compression, any more than in other types.

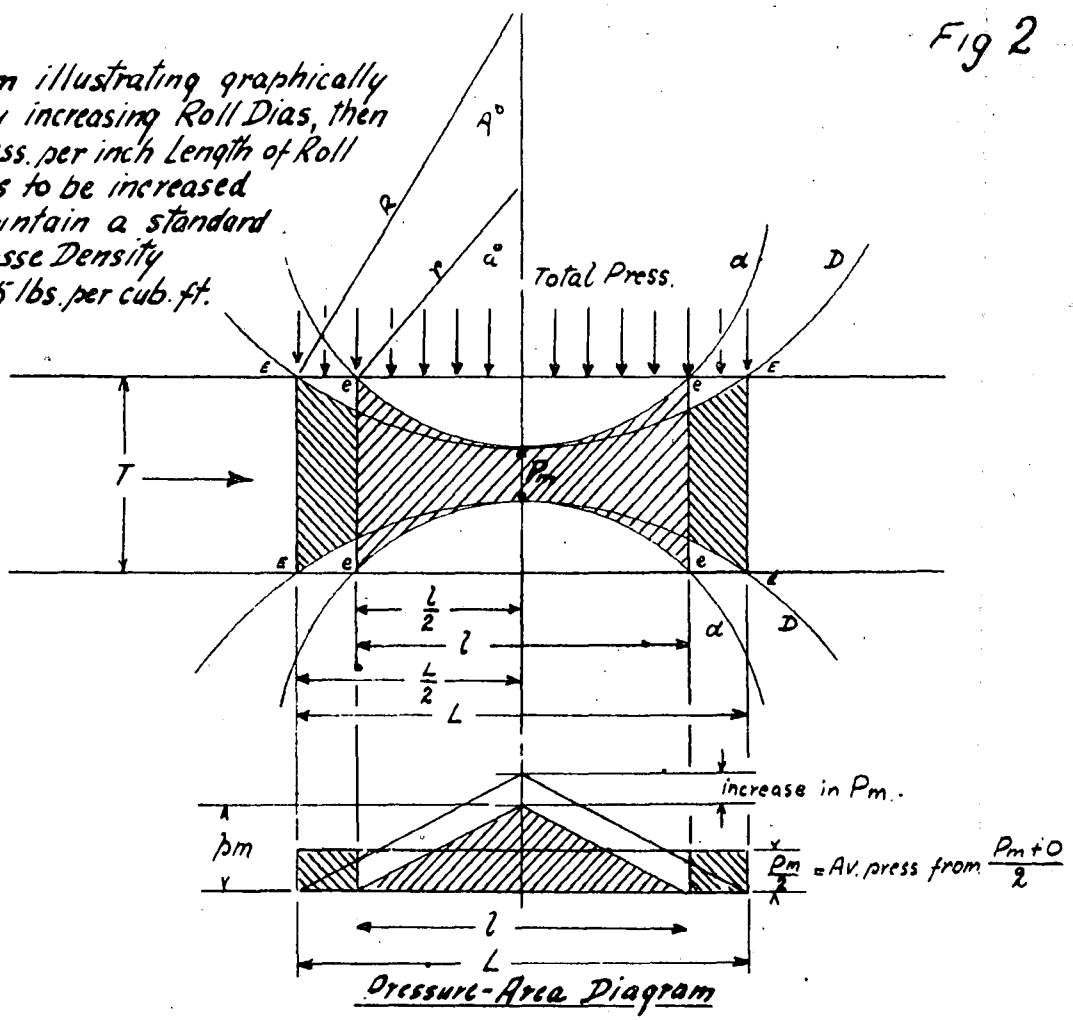
Maceration.

Next to pressure application, maceration or imbibition is the greatest single factor in extraction efficiency. Table 1 (column D) gives the maceration figures for Natal mills. These range from 27 to 41.5 per cent. on cane, and every indication goes to show that the extent of application is governed mainly by the capacity of the evaporating plant to deal with its subsequent reduction.

Temperatures of maceration water vary from 90° to 160°F. The effect of hot maceration is problematical and its use dependent entirely on the individual circumstances of the mill using it. Quite a number of those showing higher temperatures have high moistures in bagasse, and in some of these cases high feed/discharge opening ratios. This latter con-

Fig 2

Diagram illustrating graphically that by increasing Roll Dias, then Unit Press. per inch Length of Roll P_m has to be increased to maintain a standard Bagasse Density of 75 lbs. per cub. ft.



- Let T be thickness of bagasse per inch length of roll, entering smaller rolls d meeting the area of grip at $e-e$, emerging at release $e-e$.
- Then the projected surface subjected to total press $P = l$ sq.in.
- And since $l/2 = r \sin \alpha$, then $l = 2r \sin \alpha$ (1)
- Max. Intensity of press. must occur at P_m (mill setting) to nil at ends $e-e$ producing average press. $P_m/2$ over area l sq.in.
- Thus Total Pressure required to produce max. press = $P_m l/2$ tons (2)
- Similarly with larger dia. rolls D .
- Projected surface subjected to total press $P = L = D \sin A$ (3)
- Thus total press. required to produce max. press = $P_m L/2$ tons (4)

Since $L >$ than l .
 Then P_m must have increased value to produce equivalent Bag. Density as p_m .
 From 1 and 3. $\frac{d \sin \alpha}{D \sin A} = \frac{l}{L}$ and from diagram $\frac{l}{L} = \frac{24}{32.4} = 1 : 1.35$ proportionate increase.

Thus unit area increases by .35 sq.in for 60-36 = 24" increase in dia.
 Each diametral increase is $\frac{.35}{24}$ pressure increase required = .015
 Actually, increase in area, is in ratio to the sines of angles A , but between practical limits of roll diameters in use, the difference is small enough to disregard sine variation and substitute by Direct Proportion.

Examples.
 If a 24" dia. roll needs 3 tons per inch length to give density of 75 lbs
 Then 34" " " " $3 + (10 \times .015 \times 3) = 3.45$ tons
 + 38" " " " $3 + (14 \times .015 \times 3) = 3.63$ tons.

dition may be a necessity, to allow for the bagasse which has swollen to an increased volume due to heat.

Maceration has a ceiling in application, beyond which no additional gain in extraction can be expected. Audubon Experimental Sugar Factory in Louisiana¹ has published the results of a series of tests in this connection. "From 0 to 30 per cent., extraction increases rapidly, then gradually falls away until the ceiling is reached between 50/60 per cent." The curve, drawn from the results, illustrates this graphically (Fig. 3). It is doubtful, however, whether any mill would consider a gain of .2 per cent. in extraction justified by the addition of a further 15 per cent. of water. Thus it could be asserted that the effective limit of application is reached at 40 per cent. on cane.

Apart from quantity, which should be the maximum that can be effectively dealt with, the best results from maceration are dependent on other factors as well. For a given quantity, it stands to reason that slow milling speeds allow better penetrative action on the bagasse, and the graph also in Fig. 3 is self-explanatory in this respect. Adequate drainage to minimise reabsorption is absolutely necessary, particularly so on the feed side, and the general use of draining grooving emphasises this point.

Peripheral and Intercarrier Speeds.

The peripheral speed of mill rollers should be a coefficient of the respective openings. If one is increased, the other must be decreased correspondingly, in order to keep the bagasse volume a constant.

Mill speeds are also an expression of capacity, as the demands of throughput dictate the rate adopted to overcome plant limitations in other respects. To run slow with correspondingly larger openings, or to run fast with tighter settings, still forces a decision one way or other on many mill operatives. The final result often depends on the degree of efficiency demanded. Classic examples of two contending schools of practice in this respect are Cuba and Hawaii. The former adopts high speeds for throughput, even up to 50 feet per minute, while the latter tends towards the slow side with consequent greater efficiency. This is better illustrated by further reference to the graph in Fig. 3, which shows the drop in extraction rate as milling speeds are increased.

In Table 1 (column H) the average peripheral speeds listed show that the general range cannot be regarded as coming within the high category, as the average for all mills listed is 21 feet per minute. The exception is mill No. 6 with 35 feet per minute, but this can be understood as its capacity rating is high. Despite this, its extraction compares with mills Nos. 7 and 8, running at 19/20 feet per minute. This there-

fore shows the influence of the other variables on results. A good example of a non-shredding mill is No. 4, which gets 94.1 per cent. extraction at speeds averaging 16 feet per minute. Its capacity rating, however, is low. All things considered, and taking into account overseas practice, it can be said that, within general limits, there is no conclusive evidence to indicate the most efficient speed within the limits of 15 and 30 feet per minute.

While a column of average intercarrier speeds has been included, no special significance need be attached to the rates shown as having any effect on extraction. Whether to run faster or slower than the mill being fed, becomes purely a matter for individual preference. Technically, there is neither gain nor loss in relative efficiency either way. Speed and bagasse volume on intercarriers also make a constant at the following mill opening; remembering, of course, that the conditioning factor is the roll speed, to which the carrier must be accommodated. An extreme case is the one mill having an intercarrier speed of 35 feet against a roll speed of 20 feet.

Mill Settings.

While not the most important variable, yet good mill settings are the very foundation of sound milling practice. To analyse in detail the settings received from all mills and to put them in graph form, would only be a repetition of the work done by Murray⁷ in 1937 and published in the Proceedings of that year. Those graphs are certainly worth another study, as in plotting feed and discharge curves for August 1946, they show a tendency towards general improvement. It is an old assertion that mill settings are the product of individual experience and personal formula. Even Tromp⁹ does not go into detail over the subject and confines himself to the statement that settings are based mainly on past operative experience. He does mention, however, that bagasse volumes constitute a sounder basis for calculation than fibre.

If good results are being obtained in extraction, despite a badly staggered setting curve, then it is certain that the reason lies in a sounder application of the other variables. In such cases, it is understandable if settings are regarded as a minor consideration. That, however, does not indicate that the extraction would not have been better still, had they been established on sound preconceived lines. To those who wish to digest something different, the following method of using "bagasse coefficients" is put forward, with the belief that the basic reasoning is theoretically sound and more nearly approaches to conditions as they exist in practice.

Broadly, the use of bagasse U rests on the assertion that milling deals with bagasse as the constituent

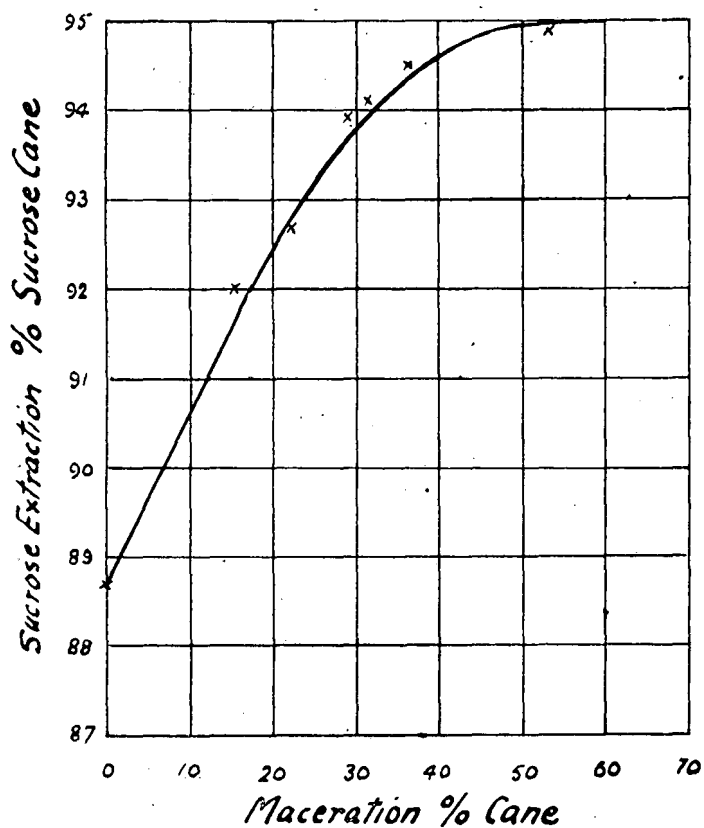


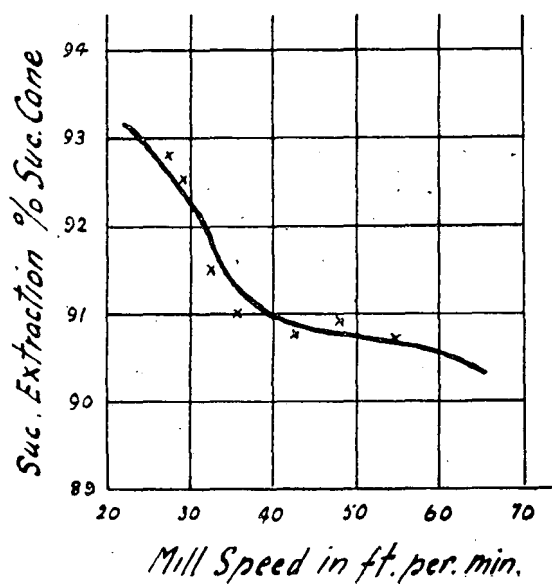
Fig. 3.

*The effect of Maceration
on extraction.*

*Other factors as constant
as possible*

*Average Moisture
in Bagasse 44.4%*

*Both these graphs have
been compiled from
"Experimental Milling Results
of the Audubon Sugar Factory"
by T. Ben Arnold. 1940.*



*The effect of Mill Speed
on Extraction*

Maceration constant at 16%

material, which is made up of fibre, moisture and sucrose in varying small amounts. The efficiency in milling depends on the extent of sucrose and moisture reduction attained in the final product. Thus it is bagasse, and not fibre, that forms true volumes in mill openings, and practical endeavour should be to calculate these openings to correspond with an ideal bagasse volume.

What is an ideal bagasse volume? Many operatives contend that fibre should be so regarded, seeing that dry fibre is the ideal to be attained. But whoever heard of anything like dry fibre as the result of a milling process? Best world practice cannot get below the 40 per cent. moisture mark with any degree of consistency, and the tests outlined under pressure application show the inordinate pressures required to reach below that mark. A mill can set volumes to accord with dry fibre, but the nett result at the required crushing rate must either be excessive top-roll lift or increase in milling speeds, in order to obey the fundamental law $Q = AV$.

Table 2 gives the actual bagasse volumes as worked out for each mill from figures given, together with the actual densities of those volumes. As they have to bear a definite relationship to one another, it will be noted that all those mills showing 45 per cent. moistures in bagasse yield densities of 74 lbs. c.f. Column C gives the ideal volumes at 75 lbs. density, which would give 95 per cent. extraction and 45 per cent. moisture. Then comes the actual last mill openings as used, and then the calculated ideal opening using the U. These figures will repay study as, for example, a picture can be presented of what is taking place in a mill which shows a discharge opening far less than its actual bagasse volume. Particular note should be made of mills 4, 7, 13, 20 and 21. The close relationship between their actual openings and the ideal derived from the U must be taken in conjunction with their high performance results as regards extraction and moisture.

It might be asked why such stress is laid on last mill settings only. This is because last mill performance is a measure of work done in the others. In any case, it alone is responsible for the extent of final moisture. Therefore the best assistance to give it is to see that each of the others in the train is doing a proportionate share of fibre pulverisation and squeezing. Reduction of absolute solids after each mill is relatively very small, being only what sugars in solution have been expressed, along with water added as maceration. Fibre and moisture maintain fairly constant volumes throughout up to the last mill, so it is not volumetric reduction that counts so much as its corresponding density. Higher densities, in turn, can only be realised by fibre disintegration, which enables the bagasse to be squeezed to smaller volumes under a given pressure.

On this reasoning, the Appendix gives the calculation for bagasse coefficients, based on absolute volume at 74.2 lbs. c. f., which corresponds to an extraction of 95 per cent. and moisture of 45 per cent.; and as they are intended as examples, the cane analysis is taken as the average that conditions during August, 1946, disclosed. These figures establish last mill discharge U. The first mill opening depends on what volumetric reduction has been made by the crusher plant. Of course, each plant could take its own tests of bagasse after the first mill and calculate the U accordingly. The examples given of first mill U for both single and double crusher, together with the first mill, can be taken as a conservative average of 50 per cent. and 60 per cent. respectively.

With the first and last mill U ascertained, the graph in Fig. 4 shows how each of the intermediate mill U is arrived at, from installations of double-crusher and four mills to single-crusher and six mills. Thus, as an example, a five-train mill with single crusher is expected to crush at the rate of 46 tons per hour. Following the line to correspond, the coefficients are read off and are as follows:—

TABLE 3.—Ratio of Feed to Discharge Settings as calculated from data for August, 1946.

Expressed in terms of area in square inches.
In each case discharge is unity.

Mill No.	1st mill.	2nd mill.	3rd mill.	4th mill.	5th mill.	6th mill.
1	2.00	1.90	3.90	—	—	—
3	1.70	1.93	1.67	2.00	2.25	—
4	2.10	2.26	1.93	2.36	2.30	—
6	1.96	1.56	2.31	2.53	3.69	—
7	3.37	3.00	2.34	3.20	3.40	—
8A	2.90	2.98	3.13	?	?	—
8B	2.72	2.90	2.20	?	?	—
9	1.72	2.25	2.38	1.93	2.03	—
10	4.98	4.20	3.60	3.72	3.40	—
11	3.60	3.73	3.51	4.66	—	—
12	1.75	2.33	2.50	2.66	—	—
13	2.19	2.34	2.00	2.25	—	—
14A	3.80	2.17	2.34	2.57	—	—
14B	2.13	2.00	2.36	2.25	—	—
15	2.47	2.56	2.43	2.80	3.20	—
16	2.13	2.20	2.28	2.51	2.84	—
17	1.65	1.59	1.51	1.58	3.12	4.10
18	2.50	2.00	m/m.	m/m.	—	—
19	2.00	1.53	2.10	2.10	2.06	2.50
Natal averages	2.55	2.47	2.52	2.65	2.88	3.30
20 (Indian)	1.97	1.94	1.87	2.00	2.16	—
21 (Indian)	2.00	1.86	2.08	1.83	1.60	—
Louisiana ..	2.00	2.10	2.20	2.25	—	—
Averages	1.99	1.97	2.05	2.03	1.88	—

Discharge opening—

1st mill = $46 \times .181 = 8.36$ C.F.M. \times Ratio = 1st mill feed
 2nd mill = $46 \times .1608 = 7.48$ C.F.M. \times Ratio = 2nd mill feed
 3rd mill = $46 \times .1405 = 6.46$ C.F.M. \times Ratio = 3rd mill feed
 4th mill = $46 \times .1200 = 5.53$ C.F.M. \times Ratio = 4th mill feed
 5th mill = $46 \times .1000 = 4.6$ C.F.M. \times Ratio = 5th mill feed

Graph giving the Discharge Opening Co-efficients for each Mill in a train of both Single + Double Crushers.

In each case, the Dis. Opening in C.F.M. is required Tons Cane per Hr $\times U$ for that mill.

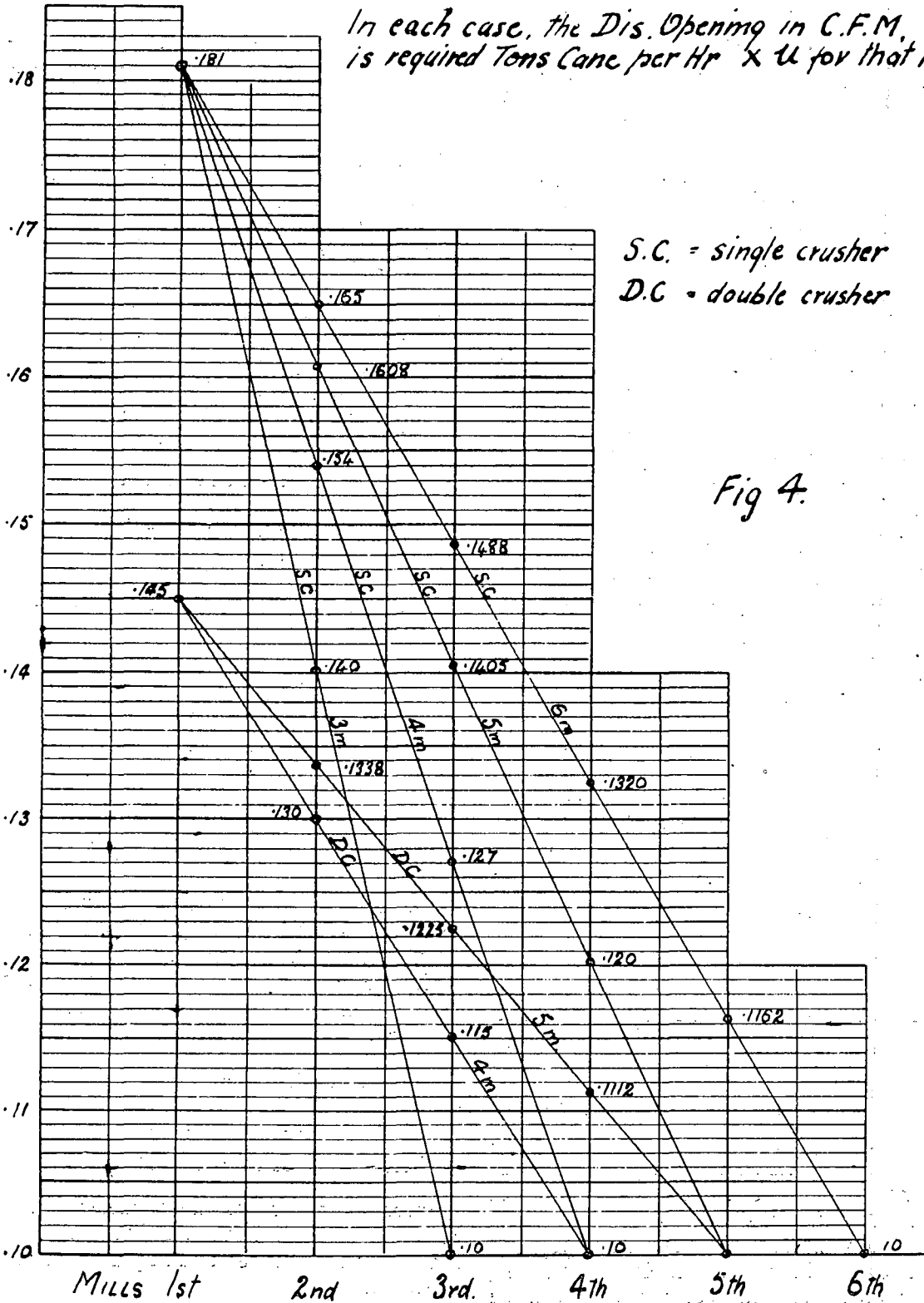


Fig 4.

The conversion of these openings in C.F.M. to area openings is the usual practice of dividing the respective results by the desired speed in feet per minute: $A = \frac{V}{S}$

The importance of keeping mill settings in proportionate ratio to one another, as shown, is more particularly emphasised when tandems have mills which are coupled or tripled to one prime-mover. In such cases, it is obvious that any discrepancy cannot be rectified merely by a change in engine speed. The advantage of individual drive to each unit thus becomes apparent, as, within limits, each mill speed can be set or varied to suit the circumstances.

As far as feed settings are concerned, the ratio can be left to individual circumstances, but bearing in mind to keep the ratio as low as possible in order to counteract the unbalanced pressure components already dealt with. Table 3 gives a list of the feed/discharge ratios for Natal, and the averages of these could well be compared with the two Indian mills, which produce such excellent results. Results from Louisiana⁶ are also given.

Trashplate Settings.—Technically, the trash or turnplate has no bearing on extraction performance, its duty being a function of transferring bagasse from feed to discharge roll action. In practice, however, it is only too well known how a badly set plate can cause faulty operational performance and large losses in time efficiency.

No useful purpose would be served in giving a list of the settings submitted, as they vary so much. However, it can be generally accepted that there is a fairly wide range of setting proportions, within which efficient results can be expected. As a rule, it is better to set on the low side rather than on the high and in terms of area, a 35/50 per cent. increase over feed opening at the toe will meet most conditions, followed by 70/100 per cent. of feed area at the heel.

Conclusion.

The milling process is in itself complicated and involved. It appears to be hedged in on all sides by masses of technical considerations, all of which have to be correlated to produce a given efficiency. Yet in the end, the solution of most of these problems rests in practical application and experience. Improvements in design and operation eventually result from a sound admixture of science, technology and practice. In this paper a lot has been said that perhaps is too well known to require repetition. Certainly a lot has been left unsaid; but if a new angle of approach towards some factors can be detected, and the results are stimulating discussion, then something useful will have been done.

Acknowledgments.

- DICK J. For data and figures relating to mill operation in India.
 HEDLEY, E. P. For determining the specific densities of various cane fibres in Natal.
 MCKENNA, H. G. . For most valued assistance generally.

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⁸ Murray, Patrick (1945): Some Notes on Cane Milling. Proc. S.A. Sugar Tech. Assoc., **19**, 39.
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APPENDIX I

Capacity Rating.

Evolving formula:—

$$\text{Tons cane crushed per hour} = \frac{D^2 \times L \times N}{6.17}$$

when D = diameter of rollers in feet.

L = length of rollers in feet.

N = number of expressions in milling train.

A shredder should be taken as one expression.

Capacity rating is a comparative term expressing that maximum quantity of cane which can be crushed by a milling train, to produce a standard result.

This standard can be expressed in any form, as long as it is generally recognised. Here it is taken as a standard final bagasse of density 75 lbs. per cubic foot and 30.85 per cent. on cane, with moisture 45 per cent. from cane with 16 per cent. fibre and 14.5 per cent. sucrose.

Capacity is due to the actual volume produced by revolving rollers and the area of opening between them. The last mill discharge opening governs this.

$$\text{Therefore: Volume} = \text{Speed} \times \text{Area.} \quad (1)$$

Speed must vary as the diameter of rollers. A 36-inch mill cannot run as slowly as an 18-inch mill; e.g. if a constant speed of 14 f.p.m. were to be considered, then

$$3.14 D \times \text{r.p.m.} = 14; \text{ and r.p.m.} = 2.98 \text{ for } 18'' \text{ roller.}$$

$$3.14 D \times \text{r.p.m.} = 14; \text{ and r.p.m.} = 1.48 \text{ for } 36'' \text{ roller.}$$

Thus, for maximum capacity, speed is proportional to diameter. Since the maximum efficient speed is 30 f.p.m., then for 37.5 inch diameter rollers this becomes 9.6 D. All other diameters give speeds proportional to this constant.

$$\text{Speed} = 9.6 \times D \quad (2)$$

Area is also proportional to diameter. Speed being already fixed in terms of the diameter, any increase in crushing rate must be met by increase in opening area, irrespective of any additional units. Standard results are supposed to be maintained through the compensating effect of added expressions and maceration applications.

Taking an opening of .25" for maximum pressure effect = 1/48 ft., then

$$\text{Area} = \frac{L \times D}{48} \quad (3)$$

Taking a normal milling train as one crusher and four mills, then the number of expressions is 9. Any additions of either crusher or mills become extra expressions and the ratio of increase in capacity is

$$\text{Expression factor} = \frac{N}{9} \quad (4)$$

Satisfying 1 from 2 and 3,

$$\text{Volume} = \frac{9.6 \times D \times L \times D}{48}$$

and at 75 lbs. bagasse density tons bagasse per hour

$$= \frac{9.6 \times D \times D \times L \times 75 \times 60}{48 \times 2000}$$

since bagasse is 30.85 per cent. cane, tons cane per hour

$$= \frac{9.6 \times D \times L \times 75 \times 60 \times 100 \times N}{30.85 \times 48 \times 2000 \times 9}$$

Thus:

$$\text{Tons of cane per hour} = \frac{D^2 \times L \times N}{6.17}$$

APPENDIX 2

Bagasse Coefficients.

Calculating a standard bagasse U for establishing last mill discharge opening in C.F.M.

For present Natal conditions, assuming ideal in milling results by extraction 95 per cent., moisture bagasse 45 per cent., fibre cane 16 per cent., sucrose cane 14.5 per cent., purity 75.

Then Fibre . . . = 2000 × .16 = 320 lbs. per ton cane
and Sucrose 2000 × .145 = 290 lbs. per ton cane

At 95 per cent. extration Sucrose in bagasse
= 290 × .05 = 14.5 lbs. per ton cane
Total dissolved solids (brix)
= $\frac{14.5 \times 100}{75}$ = 19.3 lbs. per ton cane

Weight fibre plus weight brix
= 320 + 19.3 = 339.3 lbs. per ton cane

100—moisture per cent. bagasse
= 100 — 45 = 55 per cent.

Total weight of bagasse
= $\frac{339.3 \times 100}{55}$ = 617 lbs. per ton cane

Bagasse per cent. cane per ton
 $\frac{617}{2000}$ = 30.85 per cent.

Cub. ft. fibre . . . $\frac{320}{62.4 \times 1.4}$ = 3.67 cub. ft. per ton

Cub. ft. water . . . $\frac{617 - 339.3}{62.4}$ = 4.45 cub. ft. per ton

Cub. ft. brix . . . $\frac{19.3}{62.4 \times 1.55}$ = 0.20 cub. ft. per ton

Cub. feet bagasse per ton of cane = 8.32

Bagasse density $\frac{617}{8.32}$ = 74.20 lbs. per cub. ft.

and bagasse U per ton min.
 $\frac{8.32}{60}$ = .1386.

To use this bagasse U in establishing last mill opening, allowance must be made for top-roll lift under pressure. Ideal conditions for best work would indicate not more than 25 per cent. increase in discharge opening. Any variation from this should be met by change in mill speed.

Therefore the U would become .1386 × .75 = .104. For practical purposes, the last unit can be disregarded.

Last Mill Discharge Opening U = 0.10.

Note.—This U will vary slightly, according to the cane analysis desired in any particular case. The computation will be the same, whatever variants are used.

Calculating a standard bagasse U for establishing first mill discharge opening in C.F.M.

Taking volumetric reduction by single crusher and first mill at 50 per cent, then by weight—

Fibre . . . 2000 × .16 = 320 lbs. per ton cane
Sucrose . . . 2000 × .145 = 290 lbs. per ton cane
Water . . . 2000 × .695 = 1390 lbs. per ton cane

and by volume—

Fibre . . . $\frac{320}{87.4}$ = 3.66 cub. ft. per ton cane
Sucrose . . . $\frac{290}{96.7}$ = 3.00 cub. ft. per ton cane
Water . . . $\frac{1390}{62.4}$ = 22.30 cub. ft. per ton cane

Volume per ton cane = 28.96 cubic feet
 Bagasse volume (50) $28.95 \times .5 = 14.48$ cubic feet
 Bagasse volume per ton cane per minute

$$\frac{14.48}{60} = .241$$

and $.241 \times .75 = .181$

APPENDIX 3

Calculating a standard bagasse U for establishing first mill discharge opening in C.F.M.

Taking volumetric reduction by double crusher and first mill at 50 per cent.

Bagasse volume 60 per cent. reduction
 $= 28.95 \times .4 = 11.58$ cu. ft. per ton.

and bagasse volume per ton cane minute
 $= \frac{11.58}{60} = .193$

and $.193 \times .75 = .145$

Bagasse U for 1st mill discharge
 (double crusher) 145

The PRESIDENT explained that Mr. Royston was the convener of the Milling Committee, and that the data used in this paper came largely from replies to a questionnaire sent out by this Committee. The paper was, however, original, and the ideas put forward were those of the author himself and not necessarily those of the Committee.

The paper reflected a considerable amount of work and original thought, and it offered much scope for fruitful discussion.

Mr. MURRAY said that although Mr. Royston was chairman of the Committee on Milling Practice the paper was entirely his own, as the Committee considered that an individual expression of opinion such as this would be the best contribution to our knowledge on this important section of sugar practice.

He thought that the milling of sugarcane in South Africa was more difficult than anywhere else in the world. We have excellent milling plants and these were operated by skilled milling engineers, but we could not attain extractions equal to the best in Hawaii and Queensland, etc., where the plants were not so powerful as ours. On the whole we were running over-capacity, but even plants which were not over-loaded could not achieve the extractions recorded elsewhere.

Milling technique had improved greatly in recent years, and Mr. Royston's paper is a further valuable contribution. He did not consider the load on the top roller per inch of length as given in this paper a rational way of expressing loads. He rather favoured loads per square inch of roller cross-section, as it was

more comparable. The calculated figures for our mills were as follows:—

Sugar factory.	Size of mill.	Load in tons per inch length on last mill roller.	Tons total load on top roller.	Load in lbs. per sq. ins. $D^2 \times L$ of roller.
Umzimkulu... ..	30/60	5.50	330.0	366
Renishaw	30/60	4.33	213.0	237
Natal Extates ...	37/84	3.55	298.2	195
Verulam	26/48	—	—	—
Tongaat A	37/84	4.80	403.2	258
Tongaat B	37/84	5.12	430.0	273
Chakas Kraal ...	26/48	3.75	180.0	288
Melville	26/54	3.06	165.24	235
Gledhow	34/ 6	5.75	379.5	338
Doornkop	26/54	3.70	199.8	283
New Guelderland .	24/48	2.08	99.8	172
Darnall A	30/60	5.92	355.0	394
Darnall B	30/60	5.63	337.8	375
Amatikulu	34/66	5.75	379.5	338
Empangeni	37/84	5.70	478.8	318
Entumeni	20/36	3.28	118.0	328
Umfoloji	34/66	3.93	259.38	231

The great variation in loads was apparent—from 172 to 394 lbs. per square inch. Mills were generally designed to take loads up to 400 lbs. per square inch and the low loads recorded in Natal might very well be increased. Pressure was one of the main points in striving for extraction.

Mr. Royston arrived at the following formula for indicating mill capacities:—

$$\text{Tons of cane per hour} = \frac{D^2 \times L \times N}{6.17}$$

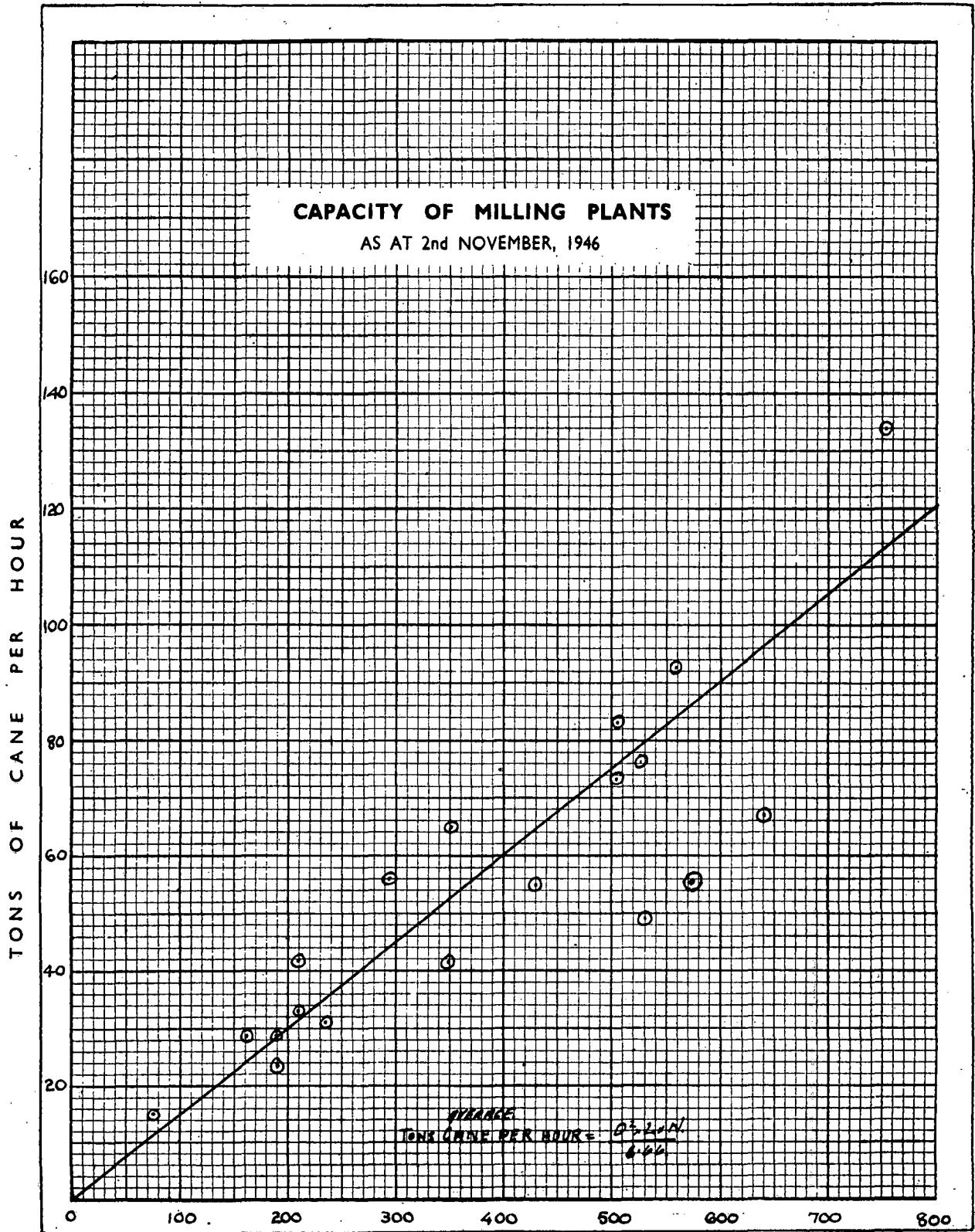
In previous papers read before this Association he had used the same formula, but N was the number of rollers, whereas in Mr. Royston's case N was the number of expressions, which was probably the more correct interpretation; and basing on the following graph plotted from the actual mill capacities the formula is:—

$$\frac{D^2 \times L \times N}{6.66} = \text{tons of cane per hour,}$$

which did not differ much from Mr. Royston's formula.

He hoped that when the Natal Sugar Millers' Association started their research department further improvements in milling would follow. Research along these lines would well repay the cost, provided it was undertaken in collaboration with the experienced mill engineers and technologists.

Mr. MACBETH maintained that there was a limit to disintegration of cane for milling purposes. Excessive disintegration did not lead to reduced volume to any great extent, especially where high-fibred cane was milled under high-capacity milling conditions, and large amounts of imbibition water were applied. It was surprising, however, that shredders were not used more in the industry, because there was no



$D^2 \times L \times N.$

D = DIAM. OF ROLLERS IN FT.
L = LENGTH OF ROLLERS IN FT.
N = NO OF EXPRESSIONS.

P.M.
14/4/47.

doubt about it where these units were used the extraction results were very good. Good disintegration materially assisted subsequent extraction in the tandem. Mr. Rault had shown that the larger particles of bagasse contained much more sucrose than the smaller portions. Volumetric reduction of crusher units as a whole were disappointing in this country, due, no doubt, to the majority of units being under capacity, necessitating large openings to accommodate the volume dealt with.

It was an acknowledged fact that the larger the diameter of rolls, the better from a feed and speed point of view, especially in crushers, and he suggested that crusher rollers should be six inches larger in diameter than mill rollers. Roll pressure was one of the most important factors in milling operations, but it was controversial and required a great deal more investigation. It was difficult to understand some of the figures given in Tables 1 and 2, where some very high last-roll pressures were nevertheless associated with high moistures in bagasse, and vice versa, and he would like to have them explained. It would also be interesting to know whether the factories recording 45 and 46 per cent. moistures were working under capacity and what the grooving on the last units were. In Hawaii, where moisture as low as 39 and 42 had been recorded, it was the practice to employ very fine grooving or no grooving at all on the top and discharge rollers of the last units. He felt, however, that where high-capacity rates were being milled in South Africa it was necessary to compromise.

In the force-vector diagram the author illustrated the hydraulic resultant based on his actual observations over a number of years, in which he recorded his findings on worn top-roller brasses. This was, however, largely the result of tandems working above rated capacity. Operators had no alternative but to employ larger openings, making for unbalanced mill settings.

The speaker could not agree with the author that, unless radical alterations in the design of mills were made, we could not hope to obtain moistures much below 45 per cent. The low moisture figures already referred to were obtained in Hawaii, and extraction over 98 per cent. with a sucrose per cent. bagasse as low as 0.9 were recorded with mills of practically the same design as used in this country. The raw material, however, differed materially in that low-fibred canes were dealt with, and rather than work at higher than rated capacities an extra tandem was installed.

He considered mill settings of the greatest importance and felt that there should be the necessary control of each individual unit of the tandem, and it was not enough to measure the work done by the other units simply on the results obtained by the last unit. The essence of good milling was to see that each individual unit was doing its fair share of the work.

Some method was required to arrive at this information. Juice density curves could be used, or, better still, the method used by Mr. Rault, who did hourly analyses (over eight hours) of each mill in rotation, and summarized the results at the end of the week.

He agreed with the author that, technically, the trashplate had no bearing on extraction, but incorrectly set trashplates could, nevertheless, influence extraction quite a lot. Thus a trashplate set too high would interfere with the normal feeding of the mill, obstructing the bagasse passing through, and resulting in poor performance of the unit. Trashplate set too low caused "balling" between the top and discharge rollers and accounted for reabsorption.

As much imbibition should be applied as the bagasse blanket would absorb, but there was no benefit gained by applying quantities that would penetrate the blanket and run back to the mill trays. The amount applied was, however, generally governed by evaporator capacity. Experiments carried out at Mount Edgecombe confirmed the results obtained by Arnold, and revealed that quantities over 40 per cent. imbibition did not materially help extraction.

The calculations in Appendix 1 were familiar and had been previously advanced by Mr. Murray. He could not, however, agree that a shredder should be regarded as one unit of expression, because shredders were simply preparatory units.

Appendix 2 on bagasse coefficients was rather controversial. The ideal milling results were based on figures which had already been bettered in this country, and surely, in addition to these calculations, other qualifications were necessary, such as plant available, amount of imbibition applied, etc., not to mention the variables that existed at each factory. All these played an important part in the final results.

Mr. RAULT said that they had found that by separating the final bagasse of about 2.2 pol. into coarse and fine particles about 55 per cent. of coarse material of nearly 3 pol. was obtained, whereas the fine bagasse had only 1.7 or 1.8 pol. This showed the importance of disintegration. At the beginning of the season milling trouble was experienced, and the engineers were inclined to blame the large quantities of Co.301 then being crushed and its tendency to pulverise as being responsible for bad milling figures. By passing bagasse from Co.301 as well as Co.281 through a quarter-mesh sieve, it was found that Co.301 did really give a larger proportion of fine bagasse than Co.281. About 55 per cent. passed through the sieve in the case of Co.301, compared with 47 per cent. for Co.281. The difference was small but from the above experiment Co.301 should, if anything, give a better extraction than Co.281.

He was inclined to agree with the author that the last unit was of very great importance in milling.

The extraction of the crusher at Natal Estates used to be 37 or 38 per cent., but when it fell to 20 per cent. the final extraction of the milling plant was still maintained, so that a difference of 18 per cent. in the first unit made no difference to the total extraction. At another factory where the crusher had done excellent work, extracting 57 per cent. sucrose, the final extraction only dropped 1.7 per cent. when the crusher broke. The same factory subsequently added a fourth mill to its train of three mills and raised the extraction by about 2.5 per cent.

Tests on individual extracting units were, however, very helpful in getting a clear picture of the whole milling operation and would help to clear up many points not properly understood.

Mr. ROYSTON agreed with Mr. Macbeth that his capacity formula was similar to that of Mr. Murray's. He could not find any capacity-rating formula in the standard books on milling that could be applied to our own conditions here, and therefore evolved this formula independently from basic hypothesis. He had no practical experience of shredder work. Thus for shredding effect on capacity he had had to rely largely on authorities in other countries and his own observational knowledge. He considered that the evidence was definitely in favour of including shredder-work in a capacity formula; that would give truer results from milling in this country.

As regards the effect of a shredder on extraction, it was interesting to note that Behne had found that cane disintegration could be overdone. Any increase in a given "fineness factor" led to a drop in extraction.

Although Hawaii might have achieved a 98 per cent. extraction with similarly designed mills as used here, our types of cane and other conditions were quite different, and we could not expect to obtain such figures here unless design conformed to our own conditions.

The extraction, moisture and sucrose percentages used in determining the bagasse U in the Appendix were questioned by Mr. Macbeth. They were used because they represented the average figures for the industry as in August, 1946. As such, they only served to illustrate the method of working out bagasse coefficients.

Engineers could use quite a different set of figures, but the data gave the procedure for ascertaining the proportional setting of mills. Mill settings should show a straight-line graph, even though individual mill extraction results lay on a curve.

He stressed the importance of last mill settings because last mill performance was a measure of the work done by the previous units, and not because other settings could be ignored.

Mr. WYATT said that Table 1 showed that those mills fitted with feed rollers gave on the average 1.54 per cent. better extraction than all others. These

figures applied to August, 1946, only and did not include all the mills; but when a season's average was taken and all mills included a difference of 1.73 in the same direction was found. The higher extraction might not be entirely due to feed rollers, but the necessity for auxiliary feed appliances, especially where mills were being run at greatly over-rated capacities, was certainly indicated.

Mr. LEWIS said he had always hesitated to recommend to his directors the installation of a shredder on account of the capital expense and repairs and maintenance costs. Mr. Royston had indicated that capacity would be increased by installing a shredder, but he wanted to know what increase in extraction could be hoped for in a mill averaging, say, 94 per cent. extraction.

In connection with imbibition, he pointed out that increased extraction obtained by the application of imbibition might easily lead to trouble in the boiling-house, as a result of the increased amounts of impurities extracted. At his factory they were trying to keep the temperature of the imbibition water as low as possible.

Mr. ROYSTON stated that Mr. Macbeth had dealt with the effect of a shredder on extraction and its cost, in a paper to this Association some years ago. The information sought for was therefore available. As far as hot imbibition was concerned, he had tried it, but discarded its use owing to operational trouble.

Mr. DICK said he was interested to observe from Table 1 that the higher roll pressures did not necessarily give high extractions. Mr. P. Murray, however, wanted to see in use, pressures increased considerably above those shown in the table.

From personal experience, Mr. Dick considered that a point could be reached—keeping in view and maintaining a given crushing capacity and other factors—where increased pressure gave little or no increase in extraction. In India he had carried out a number of tests, while maintaining a given crushing rate, by varying the hydraulic load (roll pressures), at the same time making indicator diagrams of each engine.

He had observed from these tests that excessive roll pressure, while giving little or no increased extraction, considerably increased the power required, with consequent steam consumption. Some factories may be in a position to use the extra exhaust steam; others, again, dependent on their steam balance, could not, resulting in waste.

Then again, a factory may be able to use the extra exhaust steam, but the extra power (or steam) required may necessitate additional (wood) fuel. These were important factors to keep in mind when considering advantages, if any, of increasing roll pressures.

Mr. MURRAY felt that the steam consumption of a steam engine was only very small compared to the total steam requirements of the factory, and in any case the steam could be used again.

Mr. MACBETH said he could not agree altogether with Mr. Murray in that respect. The additional steam that was used in the steam engine naturally had to come from the boiler plant; therefore, if the boiler plant could not produce sufficient steam, steam conditions would become unbalanced. It all depended on the overall efficiency of the plant generally as to whether the most use was obtained from the steam. For argument's sake, take the consumption of steam by a standard mill engine and a steam turbine back-pressure set and a steam turbine pass-out condensing combination set. The consumption was approximately 48 lbs., 28 lbs. and 16 lbs. per horse-power respectively. These figures certainly showed which units were the most economical.

Take a factory where most of the auxiliaries were electrically-driven, the h.p. steam was passed through a turbine which acted really as a reducing valve, and then passed on for process work. The overall steam efficiency was considerably higher than that where all auxiliaries were steam-driven, as the losses due to the electrical distribution system and the possible

low power factor were only a small proportion of the high steam consumption on all the steam units. The modern practice was steadily advancing towards the adoption of the electrical auxiliary drives, and in many instances mills were motor-driven as well.

Mr. MURRAY said that Mr. Macbeth was fortunate in having efficient turbines, but there were some very inefficient turbines in the industry, and in those cases a steam engine would be found to be more economical in steam demands.

Mr. WALSH said that empirical capacity formulæ had been raised several times. He would like to see the Committee try to establish a more definite formula for South Africa. The Committee should also try to find out what the comparable capacities were for other countries. He had visited other sugar-producing countries, and he had found that South Africa could be really proud of its mill performances. In 1930 he had tried to compare the work done here with other countries and he had found that some of our best mills were equal, if not better, than mills in most other countries. It was a pity Mr. Royston had quoted some figures from mills outside this country without giving all the facts, as it was more than likely they were not comparable.