On the Effect of Fibre Percentage on Extraction.

By R. M. Bechard

The following paper on the above subject was read by Mr. R. M. Bechard:—

The object of these experiments was to throw as much light as possible on the relations existing between fibre percentage and extraction, under different conditions taking into consideration other factors that might influence the results. This was done to try and solve the difficult question of determining fibre in individual consignments of cane.

The experiments were commenced last year at Tongaat, where the Tongaat Sugar Co. kindly consented to place their laboratory and equipment at our disposal, and continued at Darnall, where our thanks are due to the management of Messrs. Sir J. L. Hulett & Sons, Ltd., and especially to the chief engineer there, Mr. J. Bihl, whose advice and mechanical knowledge were instrumental in erecting the press used. Messrs. Tongaat Sugar Co. again lent their laboratory disintegrator.

Altogether, the period of testing covered 5 months during 2 separate seasons.

Apparatus Used.

For the preparation of samples, the laboratory disintegrator mentioned above was used. This apparatus (made by Messrs. Gibbens & Stream) answered the purpose admirably.

The press used at Tongaat was a hydraulic ram having a diameter of 14 inches and a travel of 10 inches, while the press used at Darnall, of which a sketch is enclosed, was constructed out of an inverted hydraulic mill headstock, having a ram of 9 inches diameter and a travel of 2 inches, the pressure being applied in the first place by a screw gear, for which, parts of a disused filter-press were used. The cylinder and plunger were more or less adapted from the specifications given by Noel Deerr in "Milling of Cane considered in relation to the volume occupied by the fibre." This work was also consulted largely as reference during the course of the experiments.

Pressure used.

A pressure averaging the load generally applied to the cane in actual milling was the pressure at which most of the tests were carried out, other pressures also being applied to investigate certain points. This pressure was a total load of 35 tons on an area of 10 square inches.

A composition of residual juice had to be decided on.

Noel Deerr states: "After chopped cane has been pressed to a certain pressure, a further notable quantity of juice can be obtained by releasing the residue from pressure and pressing again." He was able, in this manner, to extract four different quantities of juice from the same cane. This was tried, but only three pressings gave any juice. The third gave such a small quantity, that only two pressures were resorted to; the juice expressed at the second being considered residual juice. The tests were all done in duplicate, one portion of the thoroughly mixed pulp being pressed only once and the determinations done on that portion; the second portion being pressed twice, and the weights of juice and bagasse taken after the first pressure to check the first results, the second portion being preserved as residual juice. The bagasse of this juice was also tested for fibre as a check on the first determination.

As a further check, the fibre was also determined directly on the pulp by cold water extraction for fourteen hours; the results obtained being very concordant.

The juices and bagasse, after being weighed, were taken to the laboratory and tested for Brix and sucrose. The specific gravity was taken by means of a Westphal balance and converted into brix at 20–4 by the table of Windish-Buisson. The bagasse was also tested for sucrose and moisture. The residual juice was of such small quantity that it was impossible to do the direct determination, so a known percentage of the first juice was mixed with it and the Brix and sucrose determined on the mixture; the Brix and sucrose in the residual juice being calculated as follows:—

$$X = \frac{100Y - AY^1}{100 - A}$$

where X is sucrose or Brix of residual juice.
A percentage of first juice in solution.
Y brix or sucrose of mixture.
Y^1 brix or sucrose of first portion.

The quantity of disintegrated cane to be tested was the next point requiring investigation. Various quantities were then tested and the results tabulated as under.

TABLE 1.

Fibre % Cane	Pressure 7,000 lbs.-sq. inch Juice Extracted % Cane on Material 400 gms.	500 gms.	600 gms.	700 gms.	800 gms.
14.7	69.5	69.3	69.1	68.9	68.8
15.9	68.4	68.1	67.9	67.8	67.7
16.3	67.6	67.4	67.1	66.8	66.6
17.4	66.7	66.5	66.3	66.2	66.0
17.8	66.0	65.8	65.6	65.4	65.2

This would show positively that the feed affects the extraction under the conditions of the experiments. At the same time it was felt that the variations did not seem to be very large, as the changes in feed tried were of 20% which would not take place in actual milling practice, without corresponding to a decreased pressure.

Pressure Variations.—(On 500 gms. disintegrated Cane).

This was tried next, and the results tabulated as under.

TABLE 2.

Fibre % Cane	Juice Extracted % Cane at Pressure -sq. inch 7,000	6,000	4,000	1,000
16.3	67.4	66.8	65.5	62.3
16.8	67.0	66.5	64.8	61.8
17.3	66.5	66.1	64.6	61.4
19.3	64.6	64.2	62.5	59.0

We can conclude from this, that the pressure has a large bearing on the extraction opposite in effect to a reduced feed, but it was not possible to establish any relations between the two factors.

On all subsequent tests which formed the main basis of the experiments, a pressure of 7,000 lbs. per sq. inch and a quantity of 500 gms. of disintegrated cane were used, the cane being varied as to apparent physical conditions.

A loss of from 3 to 4 grams was registered between the weight of juice plus bagasse and of the pulp, when one pressure only was applied. It was apportioned two thirds on juice and one third on bagasse, and the results were then grouped as under.

TABLE 3.

Fibre % Cane	Juice % Cane	Extracted % total juice	Juice retained % Cane	Fibre % bagasse
Group 1.—Unburnt cane tested shortly after cutting.				
13.5	70.7	81.7	15.8	46.1
13.6	70.4	81.5	16.0	45.95
13.9	70.4	81.8	15.7	47.0
14.7	69.3	81.3	16.0	47.9
14.9	68.3	80.3	16.8	47.0
15.9	68.1	81.0	16.0	49.9
16.3	67.0	80.0	16.7	49.4
16.8	66.8	80.3	16.4	50.6
17.4	66.5	80.5	16.1	52.06
17.8	65.5	79.7	16.7	51.6
Group 2.—Unburnt cane tested 24 hours after cutting.				
13.6	70.6	81.8	15.8	46.3
13.8	70.1	81.4	16.1	46.2
14.0	70.0	81.4	16.0	46.7
14.9	69.2	81.3	15.9	48.4
15.0	68.7	80.9	16.3	48.0
15.8	68.4	81.3	15.8	50.0
16.0	67.9	80.8	16.1	49.9
16.5	67.3	80.6	16.2	50.5
17.0	67.1	80.9	15.9	51.7
17.6	66.2	80.4	16.2	52.1
18.0	66.0	80.5	16.0	52.95
Group 3.—Unburnt cane containing 5% of trash.				
17.4	66.0	80.0	16.6	51.2
17.7	65.5	79.6	16.8	51.3
18.1	65.5	80.0	16.4	52.5
18.4	65.3	80.1	16.3	53.0
18.9	65.1	80.3	16.0	54.16
19.3	64.6	80.1	16.1	54.5
19.9	63.8	79.7	16.3	55.0
20.5	63.1	79.4	16.4	55.6
20.9	62.9	79.6	16.2	56.3
21.4	62.3	79.3	16.3	56.8
Group 4.—Burnt cane tested shortly after cutting.				
14.3	69.7	81.3	16.0	47.2
14.7	69.4	81.4	16.9	48.0
15.5	68.4	80.9	16.1	49.1
15.9	67.9	80.7	16.5	49.5
15.7	68.3	81.0	16.0	49.5
16.3	66.8	79.9	16.9	49.1
16.4	67.8	81.2	15.8	50.94
16.8	67.0	80.6	16.2	50.9
17.1	67.1	81.0	15.8	52.0
17.3	66.7	80.7	16.0	52.0
17.6	66.3	80.5	16.1	52.3
Group 5.—Burnt cane tested 48 hours after cutting.				
15.7	68.4	81.1	15.9	49.7
16.3	67.4	80.5	16.3	50.0
16.9	67.0	80.7	16.1	51.3
17.3	66.5	80.4	16.2	51.7
17.6	66.0	80.1	16.4	51.8
18.0	65.7	80.1	16.3	52.5
18.3	65.7	80.4	16.0	53.4
Group 6.—Burnt cane tested 24 hours after cutting.				
14.5	69.6	81.4	15.9	47.7
14.9	69.0	81.1	16.1	48.1
15.6	68.5	81.2	15.9	49.5
15.9	68.3	81.2	15.8	50.2
16.1	67.7	80.7	16.2	49.9
16.5	67.2	80.5	16.3	50.3
16.7	67.4	81.0	15.9	51.2
17.0	67.0	80.8	16.0	51.5
17.5	66.6	80.7	15.9	52.4
17.9	65.9	80.3	16.2	52.5
General Average ...		80.6	16.16	

If the juice extracted % Cane is plotted out with the fibre as variable definite, the resultant will be approximately a straight line with some variations. If, however, we accept the curve as a straight line, we have a solution of the first order ; i.e., $X+Y=B$. Applying this solution we should have, $F+X=\text{constant}$, or, in this case as we are dealing with percentage, $100-C$ or $100-F-X=C$, where F is fibre % cane, X extraction in juice % cane, and C the constant. This figure C would be represented in this case, by juice retained in bagasse % cane.

On inspection of the above table we note that the maximum deviation from the average was + 0.7 and —0.4. 85% of the tests were within 0.2 of the average so that under the conditions of the experiment, i.e. with the same feed, similarly prepared but varying material and a uniform pressure applied evenly, the same quantity of juice will be retained when expressed as a percentage of the cane.

Therefore the formula,

$$100-F-X=C \text{ is applicable,}$$

$$\text{and, } 100-X=F+C \quad \text{(Equation 1)}$$

If a cane having F fibre is pressed to a bagasse having M fibre, the bagasse % cane will be, $\frac{100\,F}{M}=100-X$ (Equation 2.)

Considering equations 1 and 2 :—

$$\frac{100\,F}{M}=F+C$$

$$F = \frac{MC}{100-M}$$

It now remains to determine C.

In the Bulletin of the "Association des Chimistes de France et des Colonies," October, 1920, Vol. XXXVIII., page 113, the following formula published by the writer was accepted.

Let P^1 be sucrose % bagasse of a unit where we want to determine the extraction.

Let S be sucrose % of total cane juice: (calculated as sucrose % cane x 100) ÷ (100—fibre)

Let T be total juice % cane, as (100—fibre).

Let Y be extraction in total juice % cane.

100 bagasse will contain $\frac{100\,P^1}{S}$ total juice.

(100—Y) bagasse will contain:

$$\frac{P^1\,(100-Y)}{S} \text{ total juice.}$$

$$\text{therefore } Y + \frac{P^1\,(100-Y)}{S} = T$$

$$Y = \frac{S\,T-100\,P^1}{S-P^1}$$

Y being total juice extracted, we have now to express this value in terms of actual juice.

S is sucrose % total juice.

S^1 is sucrose % actual juice.

$$\frac{S}{S^1} = \text{total juice factor in unity} = K$$

X of actual juice will then be equivalent to KY of total juice.

$$\text{Substituting in } 100-F-X=C$$

$$\text{we have } 100-F-KY=C$$

C can also be determined in the following formula :—

$$\frac{100\,F}{M} = \text{bagasse \% cane}$$

$$\text{therefore } 100-\frac{100\,F}{M} = \text{extraction} = X$$

$$100-F-X=\text{constant}.$$

VALUE OF THE FORMULA

1. Its application to individual fibre tests.

If we go back to Table 2, and inspect the effect of pressure on the constant, we get the following figures :

Fibre % Cane	Juice Retained % cane at Pressures lbs. per sq. inch 7,000	6,000	4,000	1,000
16.3	16.3	16.9	18.2	21.4
16.8	16.2	16.7	18.2	21.4
17.3	16.2	16.5	18.1	21.3
19.3	16.1	16.5	18.1	21.7

We can now consider what sort of variations we can expect in actual milling practice. Assuming a roller of 62½ inches, grooved at 3¼ inch intervals, with grooves 2¾ inches deep, giving 18 grooves with 2 inches smooth at each end, we have a linear measurement along the face of the grooves of 119 inches. The tangential width of the line of pressure on a crusher of this type, allowing for a variation in diameter of half the depth of the grooves will be 2.65 inches, giving an area of 315 sq. inches. Each ten tons of load will give a surface pressure under this condition of 65 lbs. per sq. inch.

Variation due to feed.

If we go back to Table 1, we can express the results as:

Fibre % Cane	Juice retained % cane 400 gms.	500 gms.	600 gms.	700 gms.	800 gms.
14.7	15.8	16.0	16.2	16.4	16.5
15.9	15.7	16.0	16.2	16.3	16.4
16.3	16.1	16.3	16.6	16.9	17.1
17.4	15.9	16.1	16.3	16.4	16.6
17.8	16.2	16.4	16.6	16.8	17.0

We here see that a feed fluctuation of 20% gives us a variation of 0.2% in the retention.

2. Its application to the control of extraction.

It is hardly necessary to enlarge on that point. If this is tabulated and compared to a factor like the so-called Java Ratio, many of the queries that exist at present would have a ready answer. We all know that Java Ratio is nothing else but the Total Juice Factor into total juice % cane. The time must eventually come when the Java Ratio or Natal Ratio must disappear and the only constant used in sucrose calculation will be the Sucrose Cane Juice Factor.

This figure tabulated for 12 Natal mills for the last season in regard to extraction, Java Ratio and Total Juice is as follows :—

Mill No.	Extraction	Total Juice Factor	Total Juice	Java Ratio
1	93.75	.9173	84.75	77.74
4	88.87	.9257	84.67	78.38
5	89.44	.9030	84.25	76.07
6	90.26	.9058	84.81	76.82
7	86.70	.9252	84.38	78.07
8	87.01	.9373	82.53	77.35
10	91.13	.9023	82.97	74.86
11	86.70	.9105	84.90	77.85
12	90.01	.9051	83.81	75.85
14	89.09	.9013	84.37	76.04
16	87.78	.9051	83.67	75.73
20	89.79	.9152	84.14	77.00

It will be apparent that a high Java Ratio is reflected by a high factor, but why these variations in factor?

The following figures, although they did not prove of any use in the calculations, are appended as of general interest.

Type of Cane	Residual Juice Factor Brix	Residual Juice Factor Sucrose	Colloidal Water
Fresh unburnt	100.3	96.4	28.1
24 hours old unburnt ..	99.9	96.3	23.6
With 5% trash..	100.0	96.5	15.9
Burnt—fresh	100.1	97.0	25.4
,, 24 hour old.. ..	99.9	96.8	17.3
,, 48 hour old.. ..	99.8	96.6	11.2

Appendix to Mr. R. M. Bechard's Report re Fibre and Extraction.

Since this report was completed it was found that when the extraction was expressed in volume the resulting curve was much steadier. On going back to the volume of juice retained per 100 of Cane, the variations were found not to exceed plus or minus 0.12 of the average, so the following alternative formulae are suggested.

Substitute R (=juice retained % cane by weight) for C in the previous formulae. We then have the determination of Retention, $100-F-KY=R$ in the polarisation of bagasse method, and $F\frac{(100-M)}{M}=R$ in the fibre determination of crusher bagasse method.

C (volume of juice retained % cane) now becomes a Constant and can be derived from R by dividing this figure by the Specific Gravity.

It is, however, not thought necessary to determine the Specific Gravity of the retained juice. The figure C could have an empirical value such as that given by dividing R by the brix of the retained juice. It is desireable also to account for the difference of composition between the retained juice and the expressed juice (on which the brix determination is done), especially when the brix of the extracted juice is lowered by rain water, so the following relationship is suggested.

$$R=C\times B\times K,$$

where C will be the constant,
B brix of extracted juice,
and K cane juice factor.

Then C would be determined for a certain period, say 24 hours, as :—

$$C=\frac{R}{B\times X}$$

In individual determination from the formula,

$$F=\frac{MR}{100-M}$$

we would substitute for R as above, and have :—

$$F=\frac{M\times C\times B\times K}{100-M}$$

where C and K would be the constant for the period, and B the brix of any individual sample.

Chairman: This is a very interesting paper and represents a very large amount of experimental work. It would be a very good thing if the method of obtaining the juice extracted from the cane under standard pressure could be shown to be a reliable index to the fibre. It would provide a very convenient way out of the difficult problems of determining fibre in cane and cane sampling.

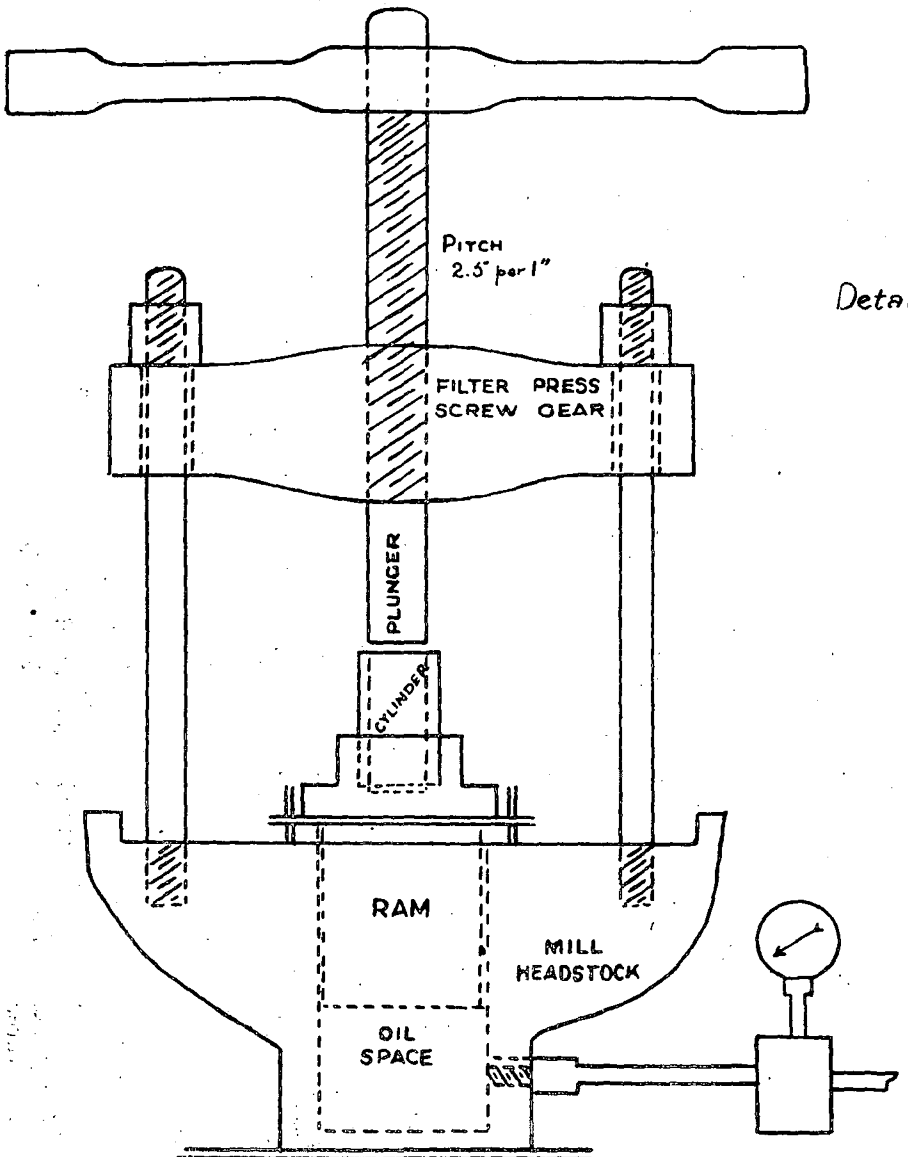
Mr. Rault: I see there is a list of fibre rising from 14 to 17. Were these canes tested about the same time, as it is very difficult to get canes of such a gradual variation about the same time? Also I remark that by working out some of the other figures from his own results that the juice in the bagasse, that is the composition of the bagasse, varied from 53 to say 46, depending on the fibre showing that a low fibre, say 14, will leave you a juice of 53 in the bagasse and a fibre of 17 would give you 46. I take it for granted that the juice is more or less proportionate to the moisture, so that in milling practice according to those figures you would expect a cane of low fibre to leave you a very high moisture in your final bagasse, and in the same way a cane of high fibre will leave you a very low moisture.

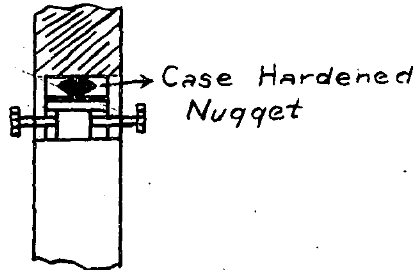
Mr. Bechard: It was extremely difficult to get the varying fibres desired. There were many more experiments carried out than are recorded, as I never knew what the fibre was going to be. The work was distributed over something like five months and during that time I sampled all kinds of cane. You will notice in one group I deliberately added fibre to the cane. On the other question that does appear to be the case. You are probably aware of the result of Noel Deerr's experiments where he has tests on canes of the same fibre all through. I might say candidly that I did not expect anything like this. I expected the more fibre the less juice it would be possible to have.

Mr. Dymond: I would like to confirm Mr. Bechard's figures. Similar tests were carried out over a wide range at Empangeni. I have tables worked out from 9 to 23 fibre. The 9 was a specimen of Badila. I would like to ask Mr. Bechard if he has gone any further and tried to obtain some relationship between fibre and the Java ratio. In the figures I have we found that there was 0.3 error, which confirms Mr. Bechard's work and is a figure we have worked on for the last two years.

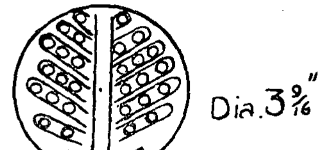
ELEVATION OF HYDRAULIC PRESS

Scale 1" to 1'.

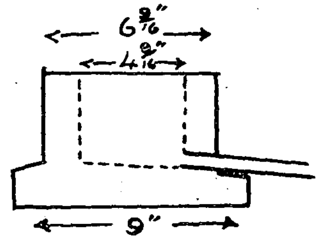




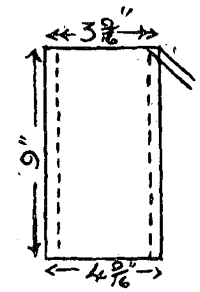
Details of Head of Plunger



Details of false Bottom.

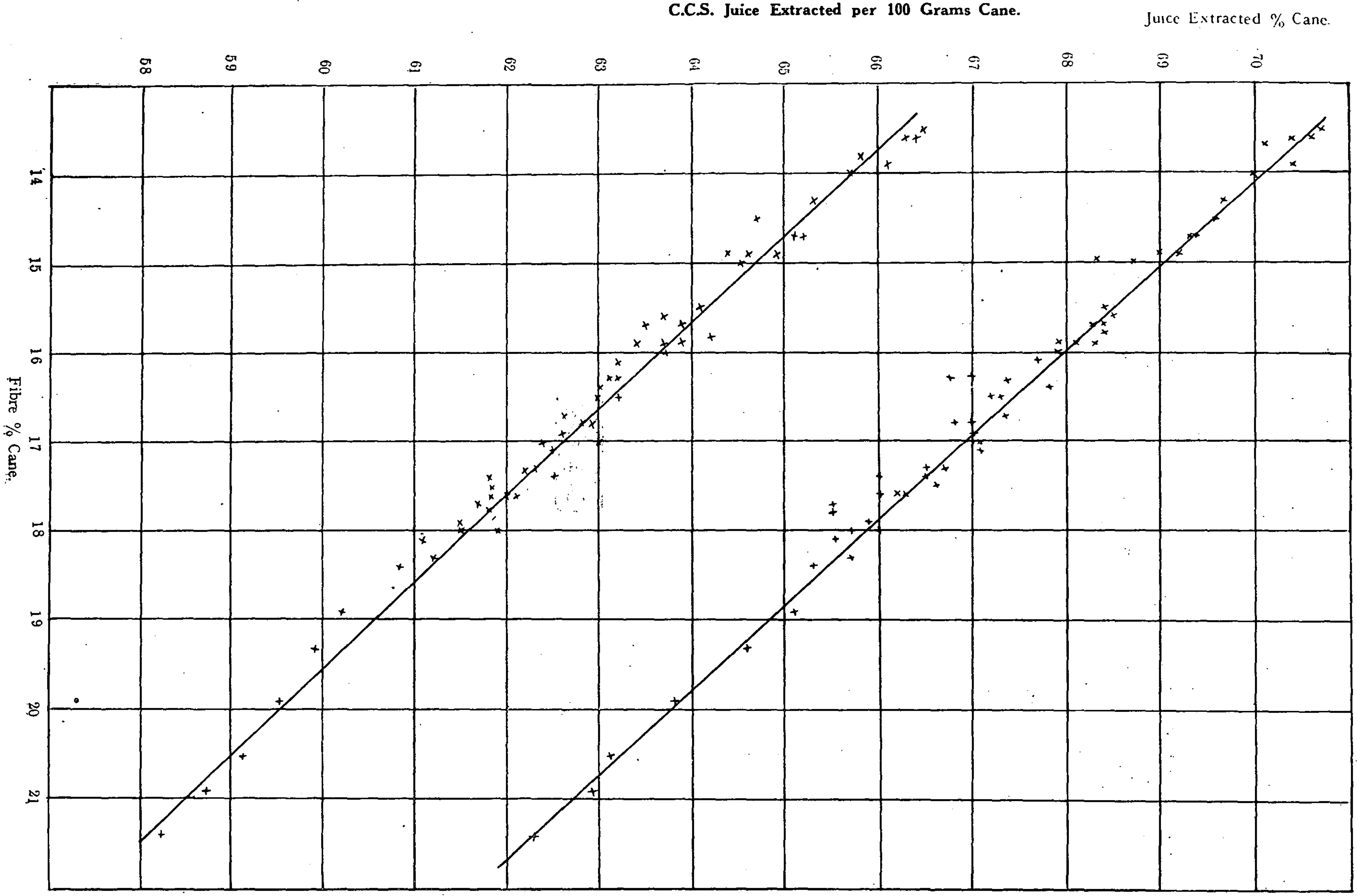


Details of Base.



Details of Cylinder.

C.C.S. Juice Extracted per 100 Grams Cane.



Mr. Bechard: When you come to the relationship between fibre and Java ratio I think the relationship is very uniform. If you consider the method of expressing the Java ratio you will note that the Java ratio is the cane juice factor multiplied by the total juice per cent. cane.

Take an example given here; you can say roughly that 1% fibre will reduce or increase the Java ratio approximately .9%. If you had an average of 76 and fibre of 16, then with a fall in fibre to 15, the Java ratio would be about 76.9.

Mr. Dymond: Fibre to-day is of much more importance in the distribution of sucrose. I think if you can get a scale for the relationship between fibre and the Java ratio you will have a table on which you can valuate every individual sample of cane. The Java ratio should range from 80 or 81 to as low as 73. A high fibre should give a low Java ratio and vice versa. Unfortunately, in practice the average Java ratio for the day is applied to all. You get one man sending in irrigated cane and he does not get the value for it. He gets paid on the average Java ratio which may be 77 when his cane may be 80; that may mean 1% sucrose to him. So that to-day I consider the determination of fibre is necessary not so much in regard to the penalty and bonus clause but for the true determination of sucrose for payment in individual samples of cane.

Mr. Bechard: What Mr. Dymond says is true. The point has been considered by the committee of fibre determination.