HOW TO MEASURE AND EXPRESS SUGAR MILLS EFFICIENCIES

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It is natural for the sugar industry to think and speak in terms of sucrose: we purchase cane and sell sugar on the basis of sucrose content; through the different phases of process, whether milling or boiling, we follow, analyse and check the sucrose to minimise losses as much as possible.

All the sucrose of the cane is not available for crystallisation as there are two factors governing extraction and recovery of sucrose:

(a) The fibre content of the cane

(b) The purity of the juice.

However efficient our milling and boiling techniques may be, some sucrose will be immobilised and retained by the fibre of the cane and by the impurities of the juice.

Bearing in mind that the aim of the milling process is to separate the sucrose from the fibre and that of the boiling process is to separate and crystallise the sucrose from the non-sucrose of the juice, sugar technologists have formulated yardsticks to measure and express efficiencies so that guidance is provided to all concerned. Such yardsticks are based on practical results.

The choice of yardsticks should be based on their merits which means that they should measure and express efficiency, accurately and correctly, hence providing guidance clearly to all concerned.

Milling

For the milling process, we have the choice of two yardsticks:

(a) The lost absolute juice % fibre;

(b) The extraction ratio.

Both yardsticks are based on the concept that the *Unit of Fibre* is the *Unit surface of Adsorption* which shall immobilise and retain the juice and sucrose.

Lost Absolute Juice % Fibre expresses the parts of absolute juice lost % fibre. Apart from the fact that the calculation of brix or solids in bagasse, hence lost absolute juice, is based on the blind assumption that the purity of the residual juice is the same as that of the last expressed juice, the term 'lost absolute juice' is fallacious for the following reasons:

(a) Absolute juice lost is calculated by dividing the brix or solids in bagasse by the brix % of the cane's absolute juice. We should remember that the solids of the cane's absolute juice and those of the residual juice in bagasse have totally different purities which means that they are of a totally different nature, one containing a higher per cent of sucrose than the other.

Is it logical to use the brix % of a raw material of a high purity to calculate the corresponding loss of such raw material from another raw material of a much lower purity? It would appear that this is quite a pertinent question bearing in mind that we are only interested in measuring and expressing the sucrose lost.

(b) As during the milling process the brix free water is never extracted and remains attached to the fibre of the bagasse, we only extract undiluted and diluted juices. Therefore, how can we use an expression which is closely associated with brix free water to measure the loss of a juice which does not contain brix free water?

For all these reasons it would appear that lost absolute juice % fibre is not a reliable yardstick to measure accurately milling losses and does not express clearly and correctly milling efficiency.

Extraction Ratio indicates the percentage of sucrose lost in bagasse as a percentage ratio of the fibre in cane.

From experience we know that the determination of sucrose in mixed juice and bagasse is far more accurate than the determination of brix or solids in such materials. Although the sucrose in bagasse is merely a Pol determination, the difference between Pol and true sucrose in bagasse is so small as to be negligible. Bearing in mind that the aim of the milling process is to separate and extract the sucrose from the fibre, it would appear that such a yardstick is accurate and representative, and therefore gives better guidance.

To illustrate how lost absolute juice % fibre can be confusing and misleading, let us take the case of two mills (A & B) crushing cane of the same quality:

Fibre %	= 15.00
Sucrose %	= 14.00
Solids %	= 16.47
Purity %	= 85.00

Mill A, being of smaller size, uses a higher imbibition to achieve the same lost absolute juice as Mill B. From experience, we know that in any particular cane, the juices of higher purities are more readily extractable and washable than the juices of lower purities as proved by the fact that in the milling process, sucrose extraction is always higher than brix extraction, which means that during the milling process, sucrose is more readily soluble or extractable than non-sucrose. Therefore, we find that Mill A, on account of a higher imbibition, has a lower purity of last expressed juice than Mill B and the whole picture is as follows:

Bagasse Analysis

MILL	*Moisture %*	*Fibre %*	*Solids %*	*Sucrose %*	*Purity last expressed*
A.	52.00	45.00	3.00	2.10	70.0
B.	48.80	48.00	3.20	2.34	73.0

Calculating the corresponding lost absolute juice % fibre, extraction ratio, absolute juice and sucrose extractions, we arrive at the following figures:

MILL	*Bagasse % Cane*	*Solids in Bagasse*	*Sucrose in Bagasse*	*Lost absolute Juice % Fibre*	*Extraction Ratio*	*Absolute juice Extraction*	*Sucrose Extraction*
A.	33.33	1.00	0.70	34.40	33.33	93.93	95.00
B.	31.25	1.00	0.73	34.40	34.80	93.93	94.78

and we find that although both mills show the same lost absolute juice, hence the same absolute juice extraction, their corresponding extraction ratio and sucrose extraction differ somewhat: Mill A's Extraction Ratio is 1.47% lower than Mill B and its sucrose extraction higher by 0.22%.

A pertinent question would be the following one: In practice, does a higher imbibition lead to a higher sucrose extraction than non-sucrose, hence a lower purity of last expressed juice or is it a mere assumption?

The following figures taken from the summary of Laboratory Reports period ending 30th October, 1965, will prove that it is no assumption but a plain fact.

	Lost Absolute Juice % Fibre	*Imbibition % Fibre*	*Extraction Ratio*
Darnall	29.22	379	29.82
Tongaat	29.26	224	31.61

Such practical findings prove that a higher imbibition will extract sucrose more readily than non-sucrose, hence a lower extraction ratio. Theoretically, we should expect the same extraction ratio for the same corresponding lost absolute juice as both are correlated to the unit of fibre. However, we find that in practice it is not true.

This illustrates clearly that lost absolute juice % fibre is not a reliable yardstick to measure and express correctly milling efficiency.

As the aim of the milling process is to separate and extract as much sucrose as possible from the fibre, it would appear that Extraction Ratio is a far better yardstick to measure and express milling efficiency.

Milling Performance

For the benefit of all concerned, it is preferable to express Efficiency as a per cent of what is available in practice, and efficiency figures are usually related to standards which have proved realisable in practice. Therefore, we suggest that a milling performance figure be introduced to express milling efficiency.

For instance, Natal Estates has proved that the milling process can achieve an Extraction Ratio of 22. Is there any objection to creating a standard of 20 as an incentive to the mill engineer's creative mind?

Should we agree to this, then the milling performance yardstick can be expressed by the following formula:

$$\frac{\text{Mill Extraction X 100}}{100-0.20\text{ F}}$$

Where F = actual fibre of the cane.

It is a simple and easy calculation and the meaning is so obvious that it would convey proper guidance to all concerned as it expresses the sucrose extracted % sucrose available for extraction.

As a matter of interest, Natal Estates Milling Performance for last crushing season was 99.22%.

Boiling

Boiling House Performance

So far, the most suitable and accurate yardstick to measure and express boiling efficiency is the Boiling House Performance as it expresses the crystallisable sucrose recovered in sugar % crystallisable sucrose available in mixed juice.

This yardstick is based upon the practical finding that for every part of non-sucrose present in the mixed juice a certain corresponding amount of sucrose will be retained in the molasses when properly exhausted.

The retention factor for calculating the non-crystallisable sucrose in mixed juice will vary according to the purity of the mixed juice as juices of lower purity (provided such low purities are not due to cane deterioration) are usually associated with a higher reducing sugar ash ratio which, as we know, helps to achieve better exhaustion as salts have more affinity for reducing sugars than for sucrose.

Bearing in mind that the retention factors represent the averages obtained from practical results, the table adjusting the retention factor according to the purity of mixed juice is as follows:

Purity Mixed Juice	*Corresponding Retention Factor*
82	0.460
83	0.470
84	0.480
85	0.489
86	0.498
87	0.507
88	0.515
89	0.523
90	0.530

The interpretation of this can easily lead to confusion, and be misleading. For instance one could say that as one part of non-sucrose will retain 0.460 part of sucrose, then the expected purity of the final molasses should be $\frac{.460 \times 100}{1.460} = 31.5$ which, as we know, is not realisable in practice. This would be a fallacious interpretation of the Boiling House Performance yardstick. The concept only means that for every part of non-sucrose present in mixed juice we must expect a certain corresponding amount of sucrose to be considered as non-crystallisable as such sucrose will be found in the molasses. However the same ratio of non-sucrose—sucrose cannot be expected in the molasses for the simple reason that some 18% of the non-sucrose is eliminated during clarification process. This means that for every 100 parts of non-sucrose available in mixed juice only 82 parts will be present in the final molasses and this changes the whole picture. It means that the expected purity of the Final molasses will be $\frac{.460 \times 100}{1.280} = 35.9$ which is more realistic.

The following figures will clearly demonstrate the vast difference between the correct and incorrect interpretation of Boiling House Performance for 82% recovery of non-sucrose in molasses.

Purity Mixed Juice	*Retention Factor*	*Correct Interpretation for expected Molasses purity*	*Incorrect Interpretation for expected Molasses purity*
82	.460	35.9	31.5
83	.470	36.4	32.0
84	.480	36.9	32.4
85	.489	37.4	32.8
86	.498	37.8	33.2
87	.507	38.2	33.6
88	.515	38.6	34.0
89	.523	38.9	34.3
90	.530	39.2	34.6

This is a totally different picture of Boiling House Performance as we know from practical experience that such corresponding purities for final molasses are obtainable in practice from such purities of mixed juice. In the light of such figures we can, therefore, conclude that Boiling House Performance represents the best yardstick to measure and express Boiling House Efficiency.

It could be said that sometimes such standards have been surpassed. We should remember that standards are based on the law of average. Any fresh juice associated with unusual high reducing sugars and low ash contents is bound to show a higher boiling house performance than the one expected from the created standard, and the application of Douwes Dekker's formula for expected purity will confirm the fact and show the green light.

It has also been found that after droughts, when the reducing sugars ash ratio is exceptionally high through cane deterioration such juices do not respond as above. This is quite in order because crystallisation of sucrose and exhaustion of molasses are not the simple result of a hypothetical chemical reaction where one part of non-sucrose will combine with so many parts of sucrose but the physical properties of the juice (viscosity) will also play an important part. Although viscosity does not prevent crystallisation, it nevertheless retards the rate of crystallisation tremendously and as the boiling house of any sugar mill is bound by the limitation of pans' and crystallisers' capacities, such deteriorated and viscous juices will lead to poor boiling house performance, however high may be the reducing sugars ash ratio.

Obviously, unusual high losses in the filter cake or in the undetermined losses, whether through entrainment or inversion, will also lead to poor boiling house performance. Excessive destruction of the reducing sugars during clarification by a too high pH would also lead to poor boiling house performance.

Overall Performance

At present, the only formula for expressing the overall work performed by sugar mills is the overall recovery. However, this yardstick is not a true reflection of a sugar mill efficiency as Mill Extraction and Boiling House Recovery are closely related to the fibre content of the cane and to the purity of the juice. It is obvious that canes of low fibre content and of high purity juice are bound to yield a higher overall recovery than canes of high fibre content and of low purity juice.

As the policy of the sugar industry is to recover as much sugar as possible from any quality of cane, we must look forward to a yardstick which will give us a true picture of our sugar mills' efficiencies. If that school of thought is correct, then the overall performance of our sugar mills must come into the picture.

It is sometimes said that mill engineers are only interested in the performance of their mills and process managers in the performance of their boiling house. This is a fallacious school of thought because without close co-operation between these two technical men, no team work can be expected to achieve the highest recovery of sugar.

But what about mill managers, general managers and directors? We would imagine that their main interests lie in the highest recovery of sugar and it is obvious that the only yardstick to express this is the Overall Performance.

Therefore, it would appear that for the benefit of both technical and financial control, an overall picture, reflecting the true efficiency of sugar mills, appears to be necessary.

An overall performance yardstick could be obtained by multiplying Milling Performance by Boiling House Performance. It would indicate the quantity of crystallisable sucrose recovered in the form of commercial sugar as a percentage ratio of the crystallisable sucrose available in cane.