A METHOD OF MEASURING CANE PREPARATION INDEX USING A COMPUTER

[1]MJ REID and [2]AGJ HASTIE

[1]*Sugar Milling Research Institute, Durban*
[2]*Transvaal Suiker Bpk, Malelane*

Abstract

A method of measuring preparation index (PI) is proposed. It uses a computer to analyse the shape of the asymptotic curve obtained from continuous measurement of the conductivity of water circulated through a sample of prepared cane. The apparatus is designed for simplicity of operation in which a weighed sample is placed in a pot and the cycle is started by pressing a button. The sequence of operations follows automatically and the PI is displayed after 10 minutes. Laboratory tests on the apparatus have demonstrated that a definite relationship exists between the PI and the shape of the curve. The correlation of various "shape factors" with the PI obtained by the present method is studied and discussed. Two prototypes of the apparatus will be evaluated at two sugar mills during the coming season.

Introduction

The method of measuring the preparation index (PI) of shredded cane presently used in the South African sugar industry is detailed in the SASTA Laboratory Manual (1985). The PI is the quotient of the brix of a sample obtained from a standard extraction procedure using a tumbler or rotating drum, and the brix of a sample obtained from a cold digester.

Although the method has been used for many years, several problems have been associated with it. Firstly it is dependent on the careful splitting of the cane sample so that the cold digester and tumbler are both provided with representative samples. Secondly the tumbler provides a single measurement of brix using a generally unreliable extraction technique. The tumbler apparatus often suffers from leaks which interfere with the brix measurement, and the time of running is critical to the accuracy of the method. Thirdly the method is fairly labour intensive because of the need to obtain two separate brix measurements. A new method is now proposed, which is incorporated in a simple apparatus which can avoid these problems.

The apparatus

The principle of operation of the proposed apparatus is the analysis of the shape of the curve obtained from a time plot of the conductivity of a solution derived from the circulation of water through a sample of prepared cane. The curve should theoretically be asymptotic, with the asymptote being the value of the conductivity of the solution which would be obtained if all solubles were extracted from the cane. The rate at which the conductivity increases during the first several seconds after circulation begins is proportional to the number of broken cells, or to the true preparation index.

This is based on the principle that the amount of soluble substance removed from a sample in unit time varies with the number of broken cells. The time-dependent relationship of this was first tested by measuring the increase of brix. This was done by taking many small samples at short time intervals from the juice circulating in a stirred pot containing a sample of prepared cane, and measuring the brix of each. The time plot of these samples gave a very smooth asymptotic curve, as expected.

The initial concept was therefore based on brix measurements possibly using a flow-through refractometer. However conductivity was also considered and when the first tests using this technique appeared to be successful, it was decided that brix measurement would be too expensive and tedious and it was abandoned in favour of conductivity.

The apparatus is arranged to pump water through a sample of prepared cane from a vessel into which a conductivity probe is fitted. The water overflows from the sample pot back into the first vessel for a period of ten minutes. A computer is used to control the sequence of operations, to log the conductivity of the circulating solution, to use a statistical method to fit an asymptotic curve to the data thus logged and to calculate the PI from the formula given in the Appendix. A diagram of the apparatus is given in Figure 1.

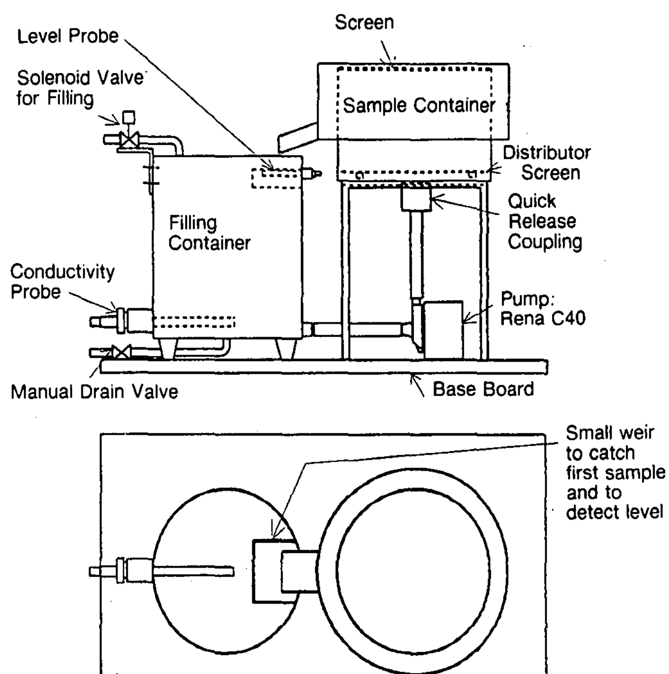

FIGURE 1 Diagram of the proposed PI apparatus.

Experimental

A prototype of the apparatus was constructed for evaluation purposes. In its first form, the circulating water was pumped from the sample pot to a distributor arranged above the sample. One of the first problems that emerged was that the solution was not adequately mixed and a discontinuity (or "blip") in the conductivity/time plot resulted.

Several tests were done with this first prototype, from which it was concluded that the method had considerable promise (Sifunda and Reid, 1993).

The second prototype reversed the direction of flow by pumping the solution upwards through the sample pot, from where it overflows into the second vessel in which the conductivity is measured. The reversal of the flow effectively removed the discontinuity in the conductivity plot.

Further testing was carried out with this second prototype (Hastie, 1994). A Jeffco shredder was used to provide samples of high preparation and a Waddell shredder for low preparation. These samples were mixed to give medium preparation.

Samples of high, medium and low preparation were tested by the existing and the new methods. Some of the data were lost or rejected because the conductivity measurement technique suffered from several minor electrical problems during the runs.

The results are shown in Figures 2 and 3. The following equations and correlation coefficients were obtained.

Test series 1: $y = 0{,}54x + 42{,}7$; $r = 0{,}95$
Test series 2: $y = 0{,}55x + 42{,}3$; $r = 0{,}92$

where y is equivalent to the PI by the new method, and x is equivalent to that by the tumbler method.

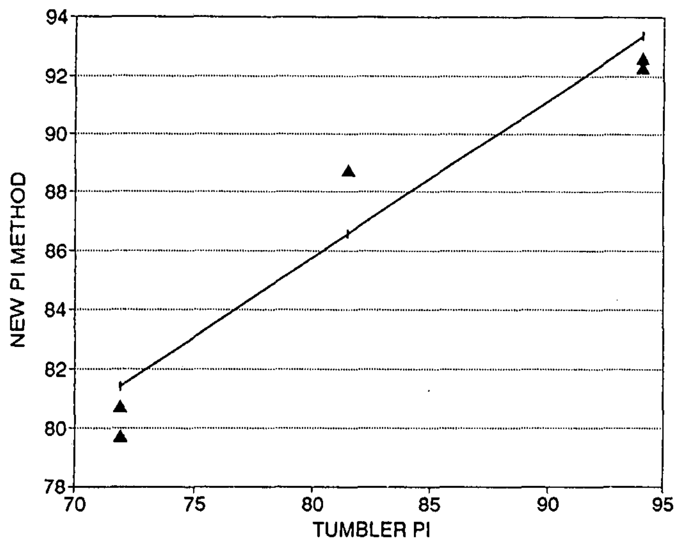

FIGURE 2 Plot of new vs tumbler PI method for test series 1.

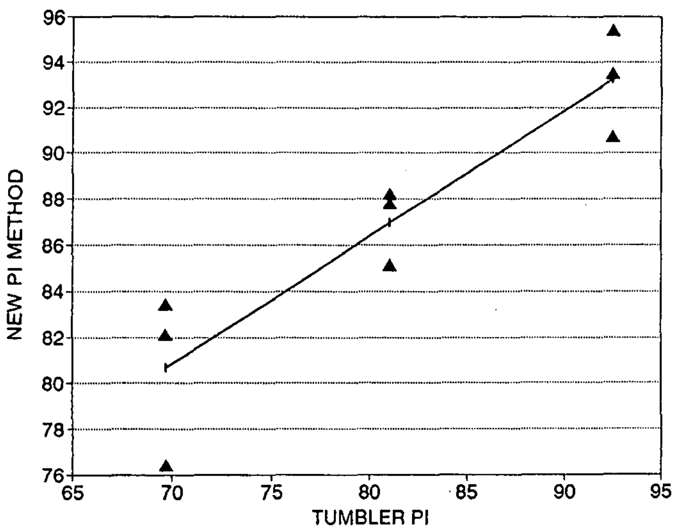

FIGURE 3 Plot of new vs tumbler PI method for test series 2.

A larger quantity of fresh cane was then passed through the Jeffco shredder. Ten consecutive sample runs were performed to establish the precision of the apparatus. One of the runs was rejected as an outlier, because the conductivity measurement was still suspect at that stage. The results of these tests are listed as test series 3 in Table 1.

Table 1
Precision test of new apparatus

Run	New PI method
9 HP	92,2
10 HP	91,2
11 HP	91,1
12 HP	90,6
14 HP	89,6
15 HP	91,4
16 HP	89,9
17 HP	92,0
18 HP	90,1
Mean	90,9
Standard deviation	0,92
95% confidence interval	90,9 ± 0,7

It was then decided to narrow the range of the preparations to represent those of the South African industry more closely. A range of 86 to 94 was chosen and samples were prepared which would give these levels of preparation as measured by the tumbler method. The results of these tests are given in Figure 4 and the equation and correlation coefficient were:

Test series 4: $y = 0{,}35x + 58{,}74$; $r = 0{,}93$

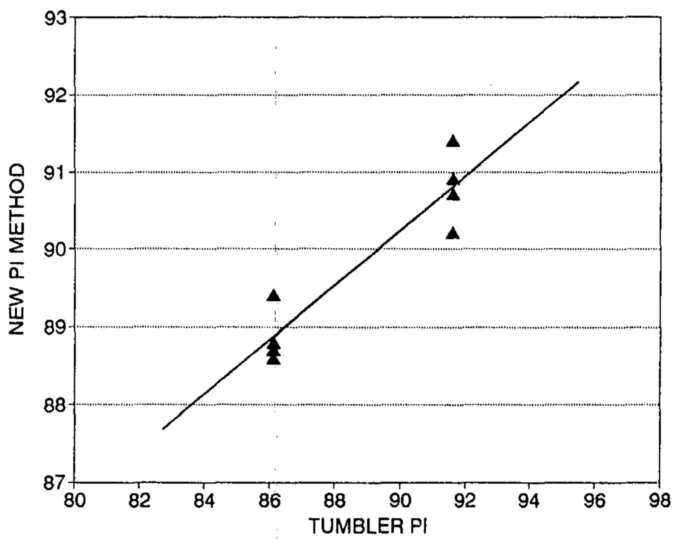

FIGURE 4 Plot of new vs tumbler PI method for test series 4.

The electrical problems were eliminated and several subsequent tests were performed to ensure that the apparatus was working satisfactorily.

Discussion

It was noticed that the asymptote obtained from the various tests with different preparations varied, being higher with high PIs and lower with low ones. This led to the conclusion that there is no absolute internal standard with the proposed method. At least with the existing method, the cold digester brix is regarded as the ultimate index and assumed to represent 100% broken cells. With the proposed method, it is only the shape of the curve which changes with preparation, and it is assumed that this shape is a sufficiently accurate indication of PI even in the absence of an internal standard. This change of shape is clearly evident from Figures 5.

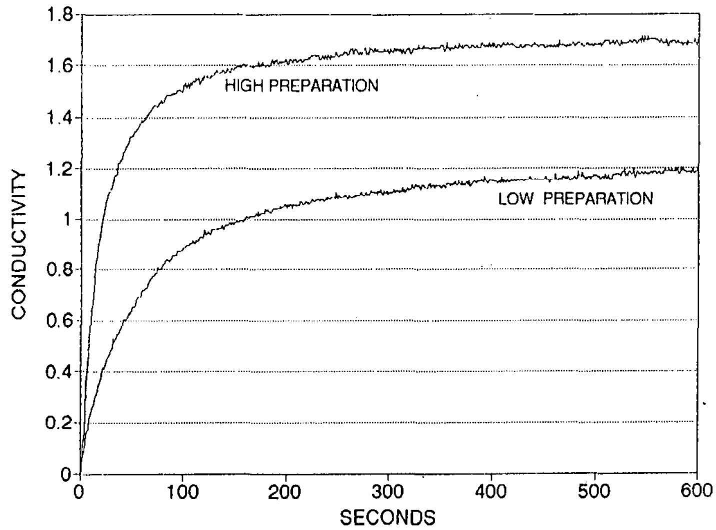

FIGURE 5 Asymptotic curves of high and low preparation tests.

In order to explore this aspect more fully, an alternative asymptotic equation was fitted to the curves, with the expectation that this equation would provide an asymptote less dependent on the degree of preparation. However, the alternative equation provided almost exactly the same asymptote as the first, simpler equation. These techniques are more fully detailed in the Appendix.

Conclusions

The relationship between the two methods is essentially linear. The precision in test series 2 is poor due to initial electrical and operating difficulties. However the apparatus can now be consistently operated with the precision found in test series 3 and 4.

The precision of the proposed method is found to be excellent, but the sensitivity to change in preparation is not as great as that with the tumbler method.

It is expected that the proposed method will result in considerable savings in time and money in carrying out a test which many engineers consider to be essential for the efficient operation of their shredders.

It may be safely concluded that the new method can be confidently pursued and that trials in the field are fully justified.

Acknowledgements

The assistance of Mr D Macfarlane and others in the SMRI workshop in building and modifying the apparatus, the help of Mr A Wienese with curve fitting and the provision of cane samples by SASEX are all very much appreciated.

REFERENCES

Anon (1985). *Laboratory Manual for South African Sugar Factories. S Afr Sug Technol Ass.* Durban p 238.

Hastie, AGJ (1994). *A new apparatus for PI determination. Sugar Milling Research Institute Internal Rep* No. 1/94. 12 pp.

Sifunda, L and Reid, MJ (1992). *Tests on a new PI apparatus. Sugar Milling Research Institute Technical Note* No. 52/92. 41 pp.

APPENDIX

The apparatus

A PVC pot with a capacity of 3000 ml is provided with a strainer and with the inlet at the bottom. The top of the pot is fitted with an overflow weir and spout, arranged to discharge into the supply vessel. The pot is attached by a quick-release coupling to the outlet from a chokeless pump with a capacity of 10 litres per minute which pumps from the 6 litre supply vessel upwards through the cane in the pot. A conductivity probe is fitted to the supply vessel and connected to the data logging input of the computer. The lowest point of this circuit is provided with a drain valve.

The supply vessel is connected to the water main through a solenoid-operated valve. This vessel is provided with a level probe which ensures that the volume in the vessel is measured accurately.

Operation

The operation commences by placing 500 g of prepared cane in the sample pot and fitting the strainer into bayonet lugs over it. The "START" button is pressed and the following operations are then performed automatically:

1. The valve opens to fill the supply vessel with 6000 ml of tap water.
2. The level probe closes the valve.
3. The pump starts and fills the sample pot from the bottom until it overflows back into the supply vessel through the small weir.
4. When the solution contacts the level probe, the measurement starts at zero time and the base conductivity is recorded.
5. The increasing conductivity level is measured by the conductivity probe and recorded every second. A temperature probe is provided for correcting the conductivity for temperature variations.
6. After the preset time (which can be varied and is presently set at 10 min) the pump stops.
7. The computer calculates the PI which is displayed on a screen together with the correlation coefficient.

After the test the pot is removed, the contents are discarded and the apparatus is rinsed by circulating clean water for a short while.

Calculations

The conductivity increases during the test asymptotically with respect to time. "Y" is the difference between the recorded conductivity and the base level, and "T" is the time in seconds from time zero. One of the formulae for an asymptotic curve is:

$$Y = \frac{T}{A + B \times T} \qquad \ldots (1)$$

A linear regression is performed of T/Y versus T. The slope is equated to B and the intercept to A. The asymptote "Y_a" is given by:

$$Y_a = \frac{1}{B} \qquad \ldots (2)$$

and the theoretical conductivity after T_1 seconds is calculated by:

$$Y_1 = \frac{T_1}{A + B \times T_1} \qquad \ldots (3)$$

The PI is then given by:

$$PI = \frac{Y_1}{Y_a} \qquad \ldots (4)$$

The value of T_1 has yet to be determined, but will probably be about 180 seconds.

The correlation coefficient r is calculated and reported by the computer separately.

Another equation for an asymptotic curve is:

$$Y = A(1 - Be^{-\sigma T} - Ce^{-\rho T}) \qquad \ldots (5)$$

Where A, B, C, σ and ρ are constants, and Y and T have the same meanings as above.

This equation was fitted to the available data for two typical runs, one of high preparation, and the other of low preparation. The values of the constant A (which is equal to the asymptote in each case) and the correlation coefficient r thus obtained by the two equations are given in Table 2.

Table 2
Comparison of two curve fitting equations

	Equation 1		Equation 5	
	A	r	A	r
High PI	1,732	0,9999	1,683	0,9989
Low PI	1,277	0,9997	1,207	0,9993

The conclusion was that because equation 1 is much simpler to programme into the computer, it would be preferred to equation 5.