Proceedings of The South African Sugar Technologists' Association — June 1986

A REVIEW OF EXPERIENCE WITH CONTINUOUS VACUUM PANS IN TONGAAT-HULETT SUGAR

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Abstract

The development of continuous pan technology within the Tongaat-Hulett Group is reviewed. Full-scale investigations in different types of continuous units is described, which culminated in a new design of continuous pan. Design features, performance trials and operating experience with this design of pan are covered.

Introduction

As one of the last remaining batch operations in sugar processing, pan boiling has received considerable attention in an effort to realise some of the advantages of continuous processing over batch processing. In general, the advantages of continuous processes have been established as better utilisation of plant, higher operating efficiencies and better process control. In the specific case of vacuum crystallisation, it was also anticipated that further process advantages could be obtained through the attainment of more uniform crystallisation conditions and improved thermal economy by the nature of the continuous process and due to the possibility of using lower quality vapours as the heating medium.

Low grade continuous pan boiling is now well established in the South African sugar industry. Within Tongaat-Hulett Sugar Limited a considerable amount of development work has taken place in continuous pan boiling, which has culminated in a new design of continuous vacuum pan used in high as well as low grade boilings. The purpose of this paper is to trace this development and relate the operating experience which has been obtained with these pans.

The First Continuous Pan Installation in South Africa

The Maidstone Mill of Tongaat-Hulett Sugar wanted to expand its pan floor capacity in 1976. At that time, Fives-Cail Babcock (F.C.B.) were most advanced in continuous pan boiling and it was a logical decision to install one of these pans as a 'C' massecuite pan. This was a 64 m^3 unit, at that time the largest continuous pan available.

The results and operating experiences with this unit have been published previously.[2] In essence, the installation was marked by the ease with which the pan was commissioned, and proved conclusively that this type of operation was viable for raw sugar mills on low grade massecuite. However, because of the high viscosity of low grade massecuites in South Africa, a number of modifications had to be made to the pan. The most significant of these was the fact that it was essential to make use of circulating steam, fed in under the calandria, to promote circulation. This is known as jigger steam and is used widely in South African batch 'C' massecuite pans as well. Subsequently, all F.C.B. continuous pans were provided with jigger steam facilities.

Even with these modifications, it was not possible to achieve the design massecuite throughput. Improved throughputs were obtained with the use of jigger steam and with calandria steam pressures of about 50 kPa gauge. The additional factors affecting throughput were found to be massecuite level in the pan and the brix profile.[6] This pan was fitted with vertical plate elements as a calandria and heat transfer performance was disappointing. An average specific evaporation rate of approximately 5 kg/h m^2 and a heat transfer coefficient of about 75 W/m^2°C was achieved.

One of the positive outcomes of this installation was the fact that it was established that a conductivity control loop on each compartment was a satisfactory way of controlling the operation of the pan. The mode of control is shown in Figure 1 and this approach has subsequently been adopted on all other continuous pan installations in South Africa.

Experiences with Converted Batch Pans

For several years no expansion was envisaged which could justify the installation of new pans. However, it was considered that if batch pans could be modified to operate continuously, then some of the advantages of continuous operation could be achieved at minimum cost. With this in mind, a batch 'C' massecuite pan at the Mount Edgecombe Mill was modified by the installation of radial baffles within the batch pan, dividing the pan into 6 equal-sized compartments. This was operated as a continuous pan by pumping seed into the first compartment and withdrawing massecuite out of the sixth compartment, via an overflow weir and a seal leg, into the crystallisers.

This arrangement worked very well. The massecuite level was kept about 500 mm above the top tube plate, so that only 16 m^3 of the 28 m^3 of the pan was utilised. Even so, the exhaustion in this pan was as good as, or better than, that achieved in similar batch pans and conductivity control of each compartment again proved to be successful.

Of interest was the fact that very much higher evaporation rates were obtained, compared to the pan at Maidstone. Specific evaporation rate averaged about 9 kg/hr m^2. This was also affected by massecuite boiling level. In this pan, the highest rate occurred with a level about 400 mm above the top tube plate. In general, evaporation rates comparable to those achieved in batch boilings were obtained.

Considerable thought was given to the massecuite flow in this pan. This is an important area and in the past the conversion of other items of process plant from batch to continuous operation has failed because inadequate attention was given to the attainment of plug flow conditions. In the Mount Edgecombe pan, cross-over ports were located above the calandria with a baffle on the downstream side of the cut-over port. With this arrangement, it was anticipated that short-circuiting would be eliminated. Tracer tests were undertaken on this pan to evaluate the flow characteristics of the system. It was found that this 6-compartment pan could be represented by a flow model comprising 9 perfectly mixed tanks-in-series. By comparison, the 15-compartment F.C.B. pan at Maidstone was also found to be equivalent to a flow system consisting of 9 tank-in-series. Clearly in the latter case, a poor approach to plug flow is obtained, with evidence of short-circuiting through compartments.[8]

At this stage, the prospect of Tongaat-Hulett Sugar building a new mill at Felixton was becoming a reality. Although

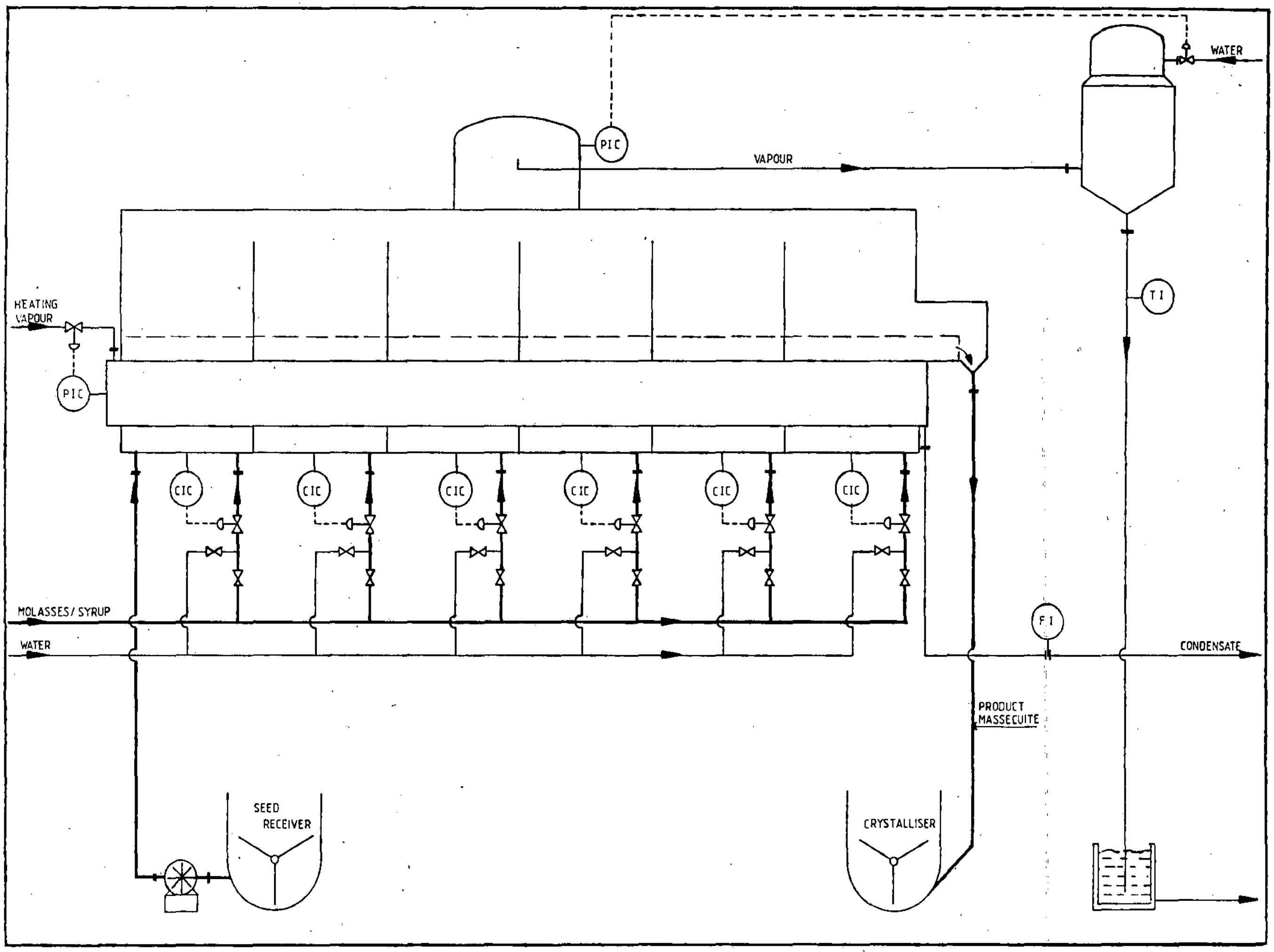

FIGURE 1 Control systems used on first Maidstone pan and subsequently on other continuous pans (*Note:* Only 6 compartments are shown).

it appeared that continuous pan boiling for low grade massecuites was a practical proposition, nowhere had a continuous pan been operated on high grade 'A' massecuites. It was decided, therefore, to convert a batch 85 m³ 'A' pan at Amatikulu in a similar way to the Mount Edgecombe conversion. This installation was not successful due to the encrustation of the heating surfaces, which meant that the pan could not be operated for more than a few days without having to take it off and boil it out. It was subsequently established that this was due to the poor circulation ratio (ratio of tube cross-sectional area/downtake area). The additional resistance which the baffle plates afforded the massecuite in the downtake meant that some massecuite was trying to find its way down some of the tubes close to the downtake and in this area encrustation was particularly severe.

However, this trial was not in vain. It established that conductivity control of continuous 'A' boilings was a feasible proposition, although encrustation of the conductivity probes meant that they had to be cleaned on a regular basis. The sugar quality and size distribution were good and some very high specific evaporation rates of around 40 kg/h m² were measured. The excellent circulation achieved with these high evaporation rates was confirmed by visual observation.

These experiments also provided data which was used to develop a computer model of continuous pan boiling,[3] which was subsequently been used for design and optimisation purposes.

The Prototype Tongaat-Hulett Sugar Continuous Pan at Maidstone

The poor massecuite flow characteristics and low heat transfer rates achieved in continuous pans in the South African industry led to the development of a new design of pan which would overcome these drawbacks. Since Maidstone Mill again needed to expand the capacity of the pan floor, a 110 m³ continuous pan of the new design was installed. Although intially planned as a 'B' massecuite pan, provision was made to run the pan on 'A', 'B' and 'C' massecuites for test purposes.

In theory, a true plug flow system is ideal in that it provides for identical residence time for all crystals in the system. In practice, this system can be very hard to control, particularly if changes in throughput rate are envisaged. It was decided, therefore, to pursue the approach of a continuous system divided into a number of compartments, with control of feed into each compartment. This system with careful design can give a close enough approach to plug flow for all practical purposes and this has subsequently been confirmed by an exhaustive series of tracer tests.

The main features of this pan were the incorporation of a vertical tube calandria to achieve better heat transfer and circulation rates and a "clean" circulation path. The pan was divided into 12 compartments, with the calandria in the centre of the pan. A plan view of this pan is shown in Figure 2. A variable height offtake weir is incorporated which

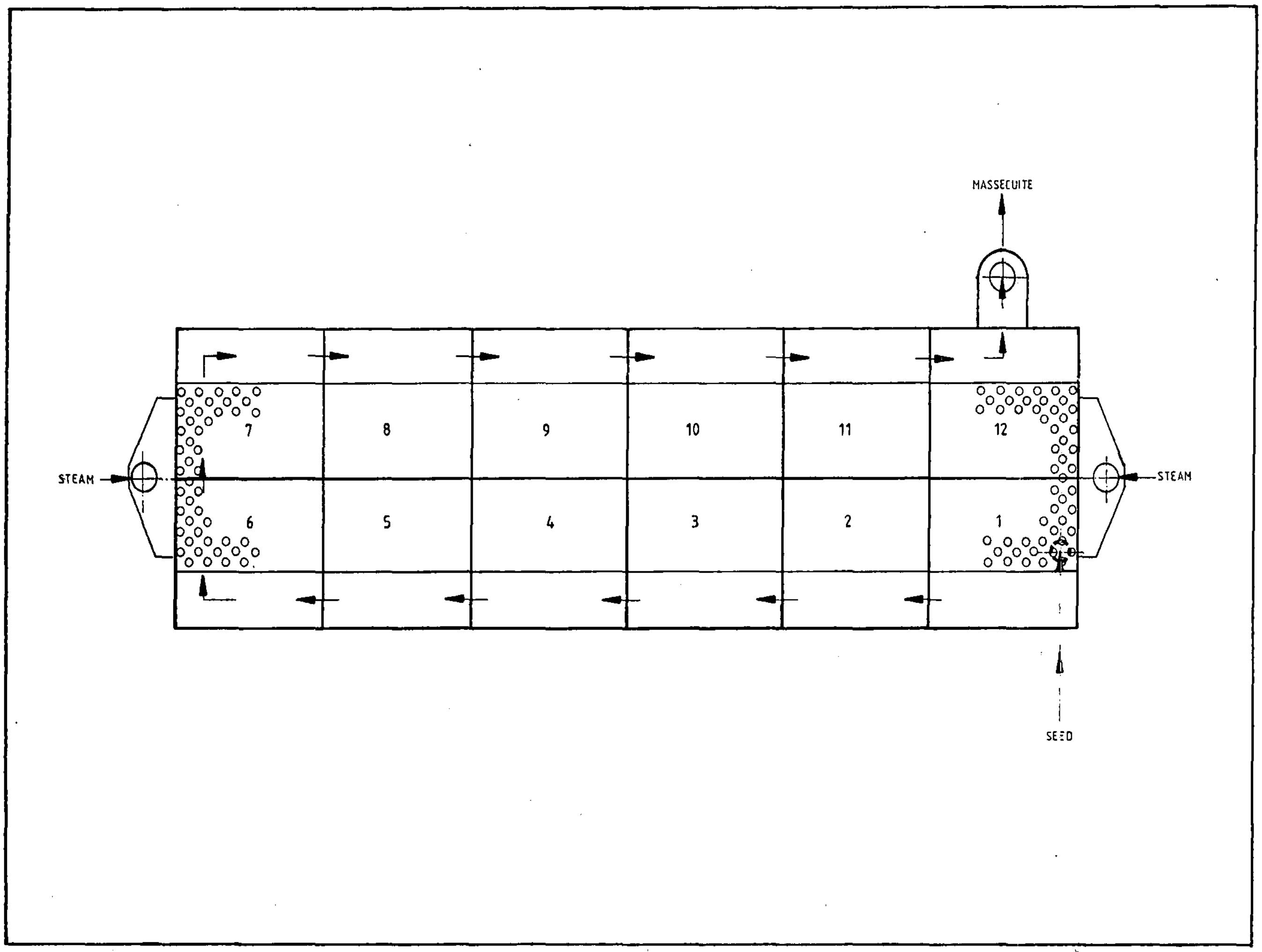

FIGURE 2 Plan view of the first Tongaat-Hulett pan installed at Maidstone

determines the boiling massecuite level. The calandria and the shape of the pan around the calandria was designed so that the massecuite circulation is similar to what is currently achieved in batch pans. The tubes are also 100 mm in diameter, but slightly longer than currently used in batch pans at 1,5 m, in order to achieve a pan of manageable proportions.

As a result, the circulation ratio is improved considerably from a figure of 2,5 in our standard batch pans, to around 1,0. Molasses or syrup is fed into each compartment under the calandria, as is jigger steam which is manually controlled to each compartment.

The results of the early experimentation on this pan have been reported by Kruger.[5] The pan has been able to operate satisfactorily on all grades of massecuite and is currently in use as an 'A' massecuite pan. The quality of sugar crystal produced by the pan is good, evaporation rates and circulation rates are high and the pan is able to operate with subatmospheric vapour in the calandria. In addition, tracer tests showed that the approach to plug flow in the pan is excellent.[8] The results of this series of tests were sufficiently convincing to allow us to proceed with the design of 'A', 'B' and 'C' massecuite continuous pans for the new Felixton Mill.

Continuous Pan Boiling at Felixton Mill

After the succesful development work at Maidstone, it was decided to install continuous pans on 'A', 'B' and 'C' massecuites in the new Felixton Mill. The new mill replaced two older mills which were shut-down and has a crushing capacity of 600 tons cane per hour. It was commissioned at the beginning of 1984, so the continuous pans have now been in operation for two seasons. Two 'A' pans, each of 120 m³ and 4 pans of 76 m³ for 'B' and 'C' massecuites were installed. All 6 pans have 12 compartments and further details of the Felixton pan floor can be found elsewhere.[9]

The design of the pans is the same as that of the Maidstone pan. Some slight modifications were made, the main one being that the tube lengths were reduced from 1,5 m in the Maidstone pan, to 1,45 m in the 'B' and 'C' pans and 1,3 m in the 'A' pan. The major difference was the incorporation of an entrainment separator and condenser as an integral part of the pan. This has the advantage of eliminating long lengths of large diameter vapour piping and the need for support steelwork for an external condenser. A cross-sectional view of one of these pans is shown in Figure 3.

Massecuite flow between compartments is via cut-over ports positioned immediately above the calandria. Baffles are installed on both sides of the port to eliminate short-circuiting and promote plug flow. This arrangement has the advantage that the opening is kept clean and free of encrustation by the vigorous boiling just above the calandria and there is virtually no hydraulic gradient from the first to the last compartment.

Commissioning of the 'B' and 'C' pans proceeded without any hitch and these pans have continued to operate without any serious problems. The operation of the 'A' pan was affected by control problems, and conductivity, capacitance and boiling point elevation have been used to control massecuite condition. In spite of control problems the new mill

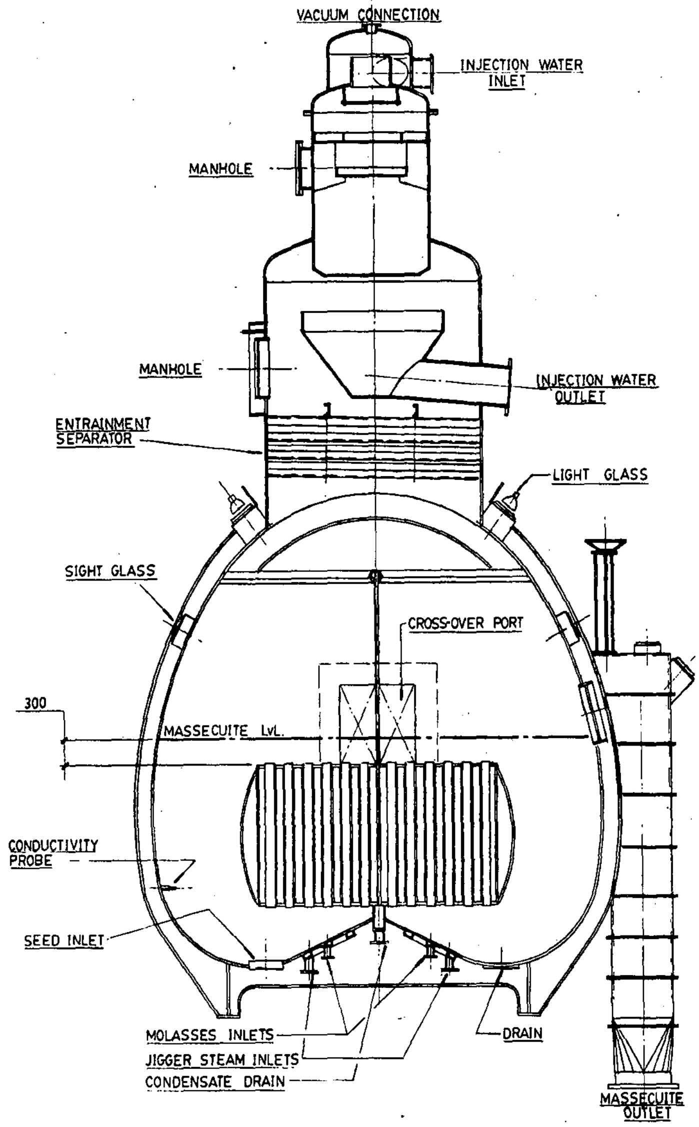

FIGURE 3 Cross-section of Tongaat-Hulett continuous pan at Felixton

has always been able to meet sugar quality specifications for VHP sugar, even towards the end of the first season when mixed juice purities dropped as low as 76 due to the influence of climatic conditions on cane quality.

The 'A' pans have been emptied every 2 weeks and boiled-out with water to remove encrustation. The process of emptying the pan, boiling-out with water and initiating continuous boiling again can be easily and conveniently done utilising the drain valves in the bottom of the pan. Massecuite from the last few compartments is struck into a crystalliser and the massecuite from the first few compartments is cut-over into a seed receiver. On starting-up again, the massecuite in the seed receiver is cut-over to the last few compartments of the pan and the first few compartments are filled with seed cut-over from a batch pan.

Heat transfer measurements on the Felixton pans have confirmed the design figures obtained from the Maidstone trials. Operation has confirmed also that calandria pressures can be kept low, at times sub-atmospheric, and that high massecuite brixes can be achieved.

Operating Experience

In general, it has been proved that continuous pans are easier to operate than batch pans and require less operator attention. Some re-education of pan boilers has been necessary, particularly to get them to accept that continuous pans should be run as steadily as possible, with a minimum of changes. Steadier and more efficient operation is achieved if the molasses or syrup feed is controlled at a constant brix and temperature and if the seed quality fed into the pan is consistent.

Perhaps the major problem experienced with these pans has been the control of massecuite brix in high grade pans. This problem has been overcome through the use of specially developed transmitters, measuring electrical properties at radio frequencies.

The success of this control system is clearly shown by the exhaustion performance of the Maidstone 'A' pan over the last few seasons. In the first year of operation, exhaustion was low. As the control problems were overcome, exhaustion improved to a point where Maidstone's 'A' exhaustion is the second highest in the South African industry, in spite of low syrup purities at this factory. This is shown in the table below.

TABLE 1

Comparison of 'A' Massecuite exhaustion figures at Maidstone with average South African mill results

	Maidstone		S.A. Industry Average	
	Massecuite Apparent Purity	Exhaustion	Massecuite Apparent Purity	Exhaustion
1981/82	85,9	61,1	85,8	63,0
1982/83	85,1	61,9	85,4	62,6
1983/84	84,0	59,6	84,6	61,8
1984/85	84,7	62,4	85,6	63,7
1985/86*	83,8	66,1	85,0	63,8

* To date figure (November 1985)

Note: Continuous 'A' pan operation at Maidstone from the 1983/84 season onwards.

It is possible at any stage to shut the steam off to 'B' and 'C' pans and stop the boiling operation. Even after lengthy mill stops the pan can within a relatively short space of time, be on-line and in production again. With 'A' massecuites, it has been found to be necessary to slacken off the massecuite a little before shutting the pan down. If this is not done, encrustation on the internal surfaces and inside the tubes can be quite severe, as the crystallisation process continues. If the pan is slackened off, however, the pan can be left out of operation for a few days and started up again with very little trouble.

Evaporation & Heat Transfer Rates

It is impossible to measure massecuite circulation in a pan directly, but heat transfer rates can be used to gauge the degree of circulation achieved. Heat transfer and circulation rates are closely related in a system such as this, which relies on natural convection. The faster the heat transfer rate, the more vapour is generated and the better the circulation. Thus, the heat transfer rates were regarded as one of the prime variables in this pan development programme.

Measurements undertaken at Mount Edgecombe in the modified batch 'C' pans yielded evaporation rates of about 9 kg/h m^2, or a heat transfer coefficient of 140 W/m^2°C. This was in line with heat transfer measurements on batch pans and roughly equal to the average value obtained in the course of a 'C' batch boiling. This is considerably better than those reported for continuous pans with horizontal tubular calandrias[4, 7].

Similarly, measurements taken at Amatikulu in the converted 'A' batch pan gave evaporation rates of about 30 - 40 kg/h m², equivalent to 450 to 600 W/m²°C. This also was considerably higher than that measured in a continuous 'A' pan in Reunion,[10] which gave an evaporation rate of 15,5 kg/h m². These results were responsible for the decision to utilise a vertical, tubular calandria in the new design.

The prototype continuous pan at Maidstone incorporated a heating surface to volume ratio of 10 m⁻¹. This was regarded as conservative, but necessary in the prototype unit. It was immediately apparent in boiling all three grades of massecuite during the trial period at Maidstone that the calandria pressure had to be reduced to about atmospheric pressure or below to reduce the overall evaporation rate. These trials led to the following evaporation rates for use for design purposes for Felixton:-

'A' Massecuite 22 kg/h m²
'B' Massecuite 10 kg/h m²
'C' Massecuite 7,5 kg/h m².

Overall heat transfer coefficients have been measured over a wide range of conditions in the continuous 'A' pans at Maidstone and Felixton. These have been found to be dependent on the temperature difference between condensing steam and boiling massecuite and some preliminary data is shown in Figure 4. Most of the data is for massecuite temperatures in the range of 60–68°C. Data obtained when purposely boiling at higher massecuite temperatures show higher values, due to reduced viscosities. Lower brix boiling improves heat transfer rates for the same reason.

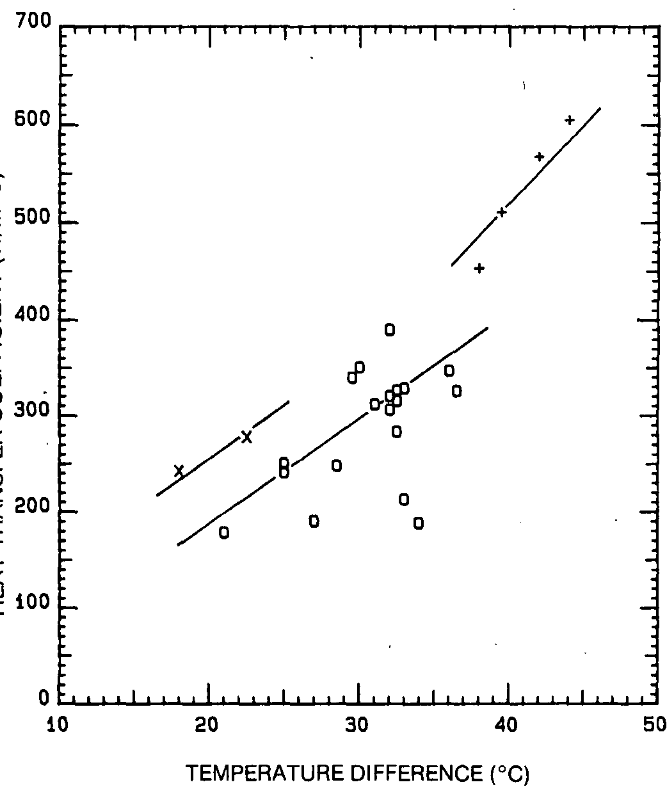

FIGURE 4 Some heat transfer coefficients measured in continuous vacuum pans boiling 'A' massecuite.

Legend: O Tongaat-Hulett pans at Maidstone and Felixton, massecuite temperature < 68°C.
X Tongaat-Hulett pans at Maidstone, massecuite temperature > 75°C.
\+ Modified batch pan, Amatikulu.

The dependence of heat transfer coefficient on ΔT is to be expected in this system which relies on natural convection. Thus, modifying the calandria pressure provides a convenient method of regulating the overall evaporation rate to meet required throughput rates.

This trend with ΔT has not been firmly established with 'B' and 'C' boilings, perhaps because jigger steam is used to promote circulation in low grade pans. Average values of heat transfer coefficient of about 180 and 130 W/m²°C have been measured on the 'B' and 'C' continuous pans respectively.

It is apparent from the figures quoted above that those achieved in the continuous pans are lower than those achieved in the early experiments in modified batch pans. This is considered to be due to the different lengths of tubes.

Experiments by the Sugar Milling Research Institute (S.M.R.I.) have confirmed that higher heat transfer rates can be achieved in shorter length of tubes.[11] Tube lengths in the Mount Edgecombe and Amatikulu pans were 1,0 m and 0,8 m respectively, while those in the Maidstone and Felixton pans vary from 1,5 m to 1,3 m. Thus, the shorter tubes appear to give better heat transfer performance. In practice, however, if the tube is made too short, it leads to a pan geometry which is very squat and wide takes up considerably more plan area. Some compromise is therefore necessary. Newer designs allow for pan tube lengths of 1,2 m to 1,3 m.

Batch pans are operated with calandria steam pressures of around 50 kPa gauge and an overall ΔT of about 45°C. The continuous pans of this design, because of their construction, are able to use low pressure vapours in the calandria and currently are operated with ΔT's of about 30°C. This provides a significant advantage if thermal economy is of importance. At Felixton, Vapour 2 is used in the calandrias to enable the mill to supply sufficient bagasse to a downstream paper mill without having to burn coal. Clearly, the heating surface to volume ratio can be adjusted at the design stage to suit the particular conditions under which the pan is required to operate.

Residence Time Distribution

A large number of tracer tests have been undertaken on continuous pans in South Africa by the SMRI and Tongaat-Hulett Sugar.[8] The reason for this was to assess the approach of the flow system to plug flow, bearing in mind that significant variations from plug flow conditions could lead to variations in crystal residence time, which would significantly affect crystal size distribution.

The tanks-in-series model has been used to characterise the flow system. With this model, a true plug flow system can be represented by an infinite number of well-mixed tanks-in-series, while a complete back-mix system is represented by only a single tank. Most flow systems fall somewhere between the two extremes. Experience with the converted batch pans showed that it is important to give careful consideration to the way in which massecuite flows within each compartment and from one compartment to the next. The modified batch pans and Felixton pans have a cut-out immediately above the calandria in the compartment walls, through which massecuite passes from one compartment to the other. Suitable placement of baffles before and after the openings ensures that no short-circuiting will occur. In the Maidstone pan, the cross-over duct from one compartment to the other was positioned in the downtake, in the form of a "postbox chute", diverting massecuite flowing down the downtake from one compartment to the next. The design of this cross-over port was such that short-circuiting across the compartment would be very unlikely.

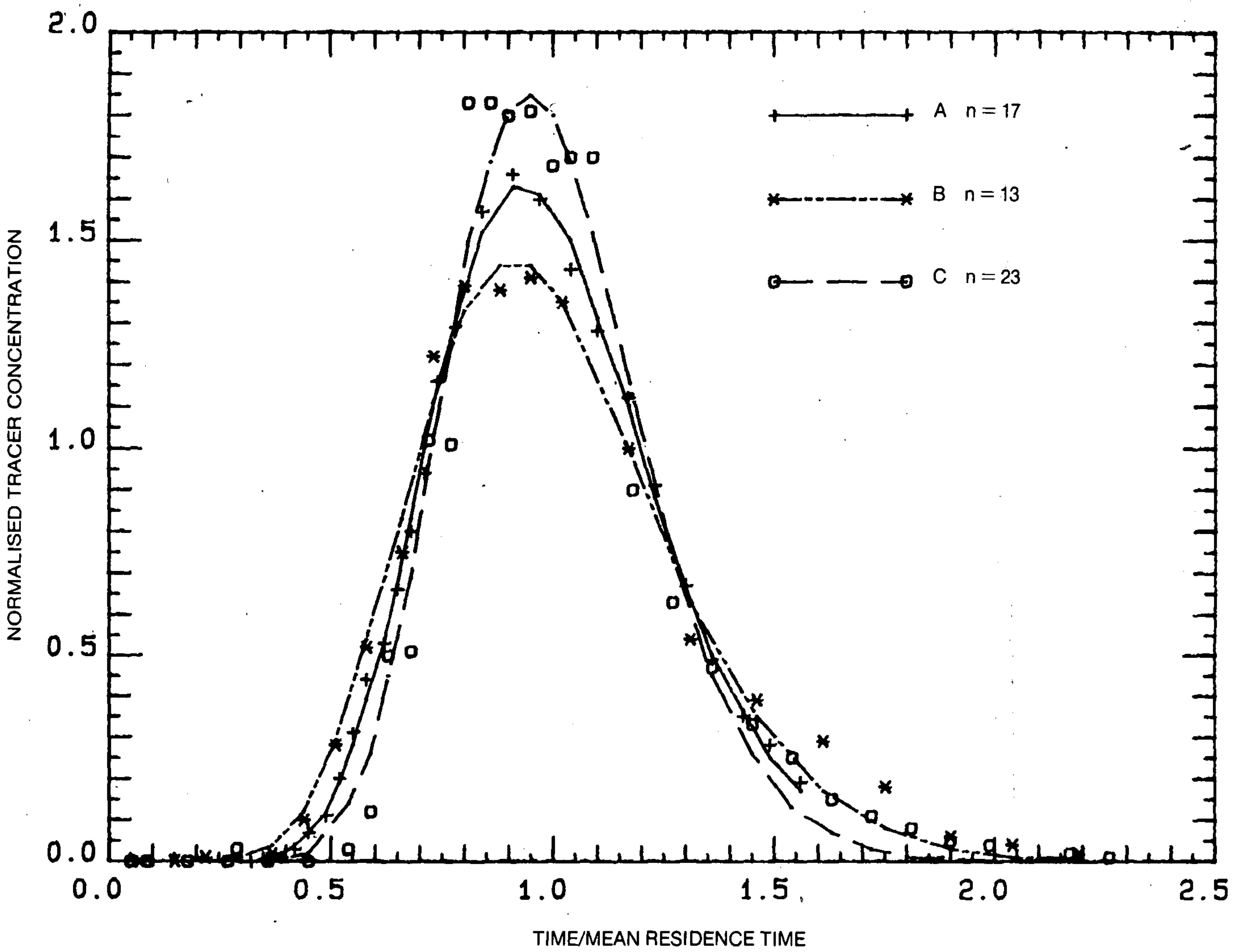

FIGURE 5 Residence time distribution measured in the Tongaat-Hulett pan at Maidstone boiling 'A', 'B' and 'C' massecuites. Lines represent best fit of tanks-in-series model (n is the equivalent number of tanks).

In practice, tracer tests at Maidstone and Felixton have confirmed the results achieved in the Mount Edgecombe pan tracer tests. These pans have shown that the flow system is equivalent to somewhere between 12 and 23 tanks-in-series. The results of the tracer tests at Maidstone are shown in Figure 5.

These pans give a closer approach to plug flow than other continuous pans in service in South Africa[4, 7, 8].

Sugar Quality

It is not possible to make firm statements about the quality of sugar obtained in batch pans compared to that obtained in the continuous pan unless the two can be operated side-by-side, since large variations in cane quality occur which have a profound effect on sugar quality. When the change was made from batch 'A' pan boiling to continuous 'A' pan boiling at Maidstone, an improvement in sugar colour, although small, was noticeable and the operators were able to reduce the water wash on the 'A' centrifugals.[5]

At Felixton, no difficulty has been experienced in achieving VHP sugar quality, even in an area which was previously known for its poor cane quality. In this case, however, sugar quality is also improved by the operation of a syrup clarifier.

A few measurements were done at Maidstone by boiling some batch 'A' boilings to compare with the continuous 'A' pan. Six sets of comparative tests were done and the average results are shown in Table 2. These results show that the sugar, in terms of crystal size and CV, was very similar. However, a statistically significant reduction in the colour of the affinated sugar from the continuous pan of about 16 % relative to that from the batch pan was achieved.

Table 2

Comparison of 'A' Sugar produced by batch & continuous pans at Maidstone, from the same 'A' seed

	Massecuite				Sugar
	Brix	Purity	Mean Aperture (mm)	C.V.	Colour of Affinated Sugar (ICUMSA 420)
Batch	90,8	83,6	0,73	27	820
Continuous	92,3	83,9	0,72	28	690

Crystal Size Distribution

A considerable amount of attention was given to crystal size and size distribution of 'A' sugar, since it is required to meet VHP specifications for size and percentage fines. Most attention was given to the coefficient of variation or CV of the sugar, particularly in comparison with sugar from batch pans. It has been shown that if equivalent CV values can be achieved while achieving the required average crystal size, limits on fines are easily achieved.[5]

In the Maidstone pan, it was found that the improvement in CV from seed to massecuite was of the order of 6 units, which was virtually identical to that measured in batch pan boilings.

It has been clearly shown that the CV of the crystal in massecuite depends very much on the CV of crystal in seed.[8] Some data obtained is shown in Figure 6. This emphasises the need to prepare a seed of good quality.

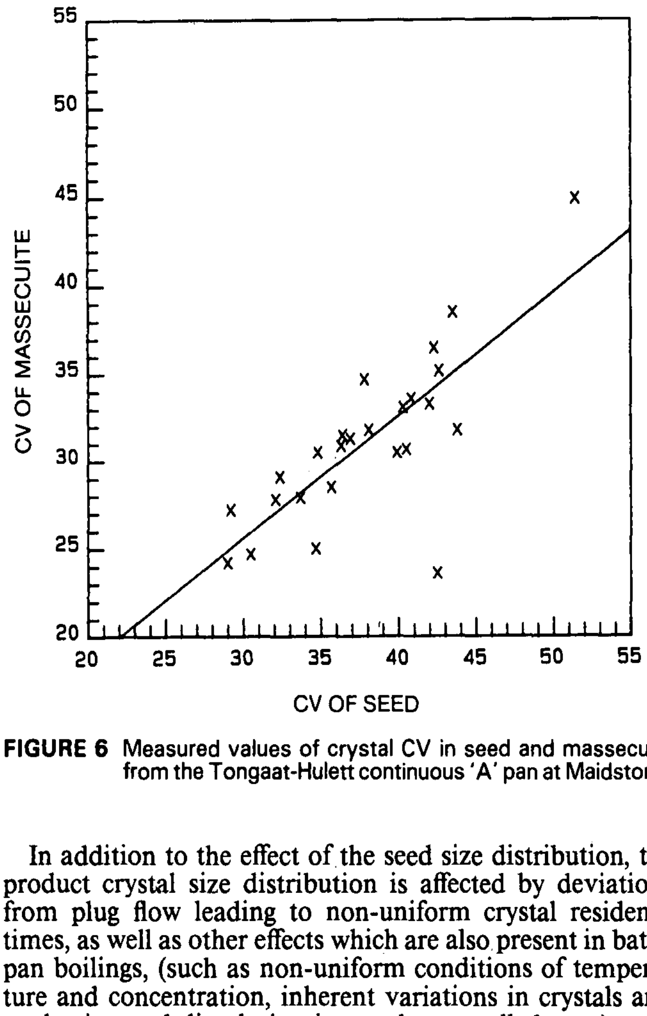

FIGURE 6 Measured values of crystal CV in seed and massecuite from the Tongaat-Hulett continuous 'A' pan at Maidstone.

In addition to the effect of the seed size distribution, the product crystal size distribution is affected by deviations from plug flow leading to non-uniform crystal residence times, as well as other effects which are also present in batch pan boilings, (such as non-uniform conditions of temperature and concentration, inherent variations in crystals and nucleation and dissolution in poorly controlled pans).

From the measurements taken at Maidstone, the variance in crystal size distribution due to non-ideal flow conditions was evaluated relative to that due to these "other" effects.[8] It was shown by a simple analysis that for 'A' massecuites, if the flow system can be represented by 4 tanks-in-series, the variance due to the flow system is just slightly more than that due to other effects. However, if the pan approximates a flow system of 16 tanks-in-series, the dispersion due to the flow system is only just over a quarter of the other effects.

From this analysis, the expected change in CV from seed to massecuite can be calculated and the results are shown in Figure 7. Note that this only applies to South African 'A' massecuites.

The results are only approximate, but they nevertheless show firstly that a bigger change in CV occurs from seed to massecuite when the CV of the seed is high, and secondly that provided the flow system approximates to more than

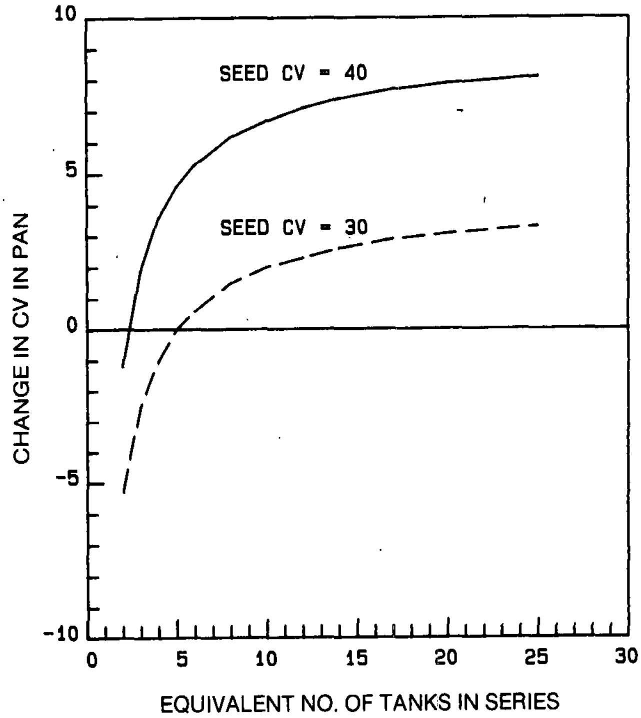

FIGURE 7 Calculated change in CV from seed to massecuite, based on measurements in the continuous 'A' massecuite pan at Maidstone, as a function of the equivalent number of tanks-in-series.

about 14 tanks-in-series, the penalty due to deviations from plug flow in terms of CV will be less than 1,5 units. In practice, there is evidence to show that because of more uniform growth conditions in a continuous pan relative to a batch pan, the variance in crystal size could actually be superior to that achieved in a batch pan[1,8].

Instrumentation & Control

A schematic diagram of the control systems utilised is shown in Figure 1. In essence, there are 14 control loops, a conductivity control on each of the 12 compartments and in addition, a calandria pressure control loop regulating the steam flow to the calandria and an absolute pressure control loop regulating the water flow to the condenser. Measurement of the condensate rate from the pan is considered to be important as a means of assessing production rate, and seed pump feed speed is indicated and regulated at the pan. In general, the ratio of massecuite rate to seed rate is about 3 : 1, but this can be varied to suit the seed crystal size and required massecuite crystal size.

In 'B' and 'C' massecuites, conductivity is a completely adequate means of controlling the feed to each compartment.

In 'A' pans, conductivity can still be an effective means of control, providing that the probe can be kept clean. In practice, it has been found that this means cleaning the probe at least once every 8 hours. It appears that immediately a probe has been cleaned, there is a fairly quick but small build-up on the probe, which changes its level and then drifts off more slowly as encrustation progresses. Steam sparging onto the probes has not proved to be effective and it was found necessary to actually remove the probes and clean them by hand. In addition, in 'A' massecuites the relationship between conductivity and massecuite brix does change regularly and this needs to be checked by the operators.

For this reason, a different measurement technique has been devised, which makes use of the measurement of electrical properties at radio frequencies in the range of 20 MHz to 50 MHz and is less sensitive to encrustation or scaling. This probe, together with a micro-processor, is able to measure the reactive and resistive properties of the massecuite and from these measurements infer both crystal content and mother liquor properties.

Suitable combination of these signals provides a measurement which enables massecuite quality to be effectively controlled. The system is still under development, but has been used with success at Maidstone on the 'A' pan, as can be seen from the high exhaustion figures given previously.

Boiling point elevation control has also been used for controlling feed to each compartment on the Felixton 'A' pans. Boiling point elevation is more suited to control in a continuous pan because the hydrostatic head is constant, as is the absolute pressure. Its main drawback is that it is not affected at all by the crystal content.

Other control strategies involving either the maintenance of a fixed ratio between seed and molasses or syrup feed or the maintenance of a fixed evaporation rate are possible. At Felixton, the required evaporation rate, measured by condensate flow, is set and the calandria pressure is automatically varied to achieve this. This helps to share the load equally between the two 'A' pans. In practice, however, if all the other factors affecting crystallisation, such as seed crystal quality and molasses or syrup feed conditions are steady, more elaborate control systems are not required.

Encrustation

In a batch pan operation the pan is steamed-out regularly and the build-up of sugar layers or encrustation on the internal surfaces of the pan is not a problem. In a continuous pan, sugar encrustation is not regularly removed and can cause problems. Generally, it has been found that this encrustation is highly dependent on the massecuite purity.

In 'B' and 'C' massecuites, encrustation is not serious and the pan can be operated for long periods of time without having to empty and boil-out the pan with water. In some cases, 'C' pans have been run continuously throughout a season without emptying at all and 'B' pans have operated with just a few boil-out periods during a 38-week season. Visual evidence inside 'B' and 'C' pans shows that some of the encrustation which does occur breaks off in layers.

Encrustation in 'A' massecuite pans, where the purity is around 85, is far more severe. It has been found at Felixton and Maidstone that an 'A' pan can easily run for 2 weeks without having to be emptied and boiled-out. In some cases, this period between boil-outs has been extended to over 4 weeks, but generally a routine of 2-week periods has been established, which coincides with weekly maintenance stops. 'A' massecuite purities have spanned the range of 80 to 87. No dependence on purity has been evident over this range.

A system of fine water sprays was installed in the continuous 'A' pans, the objective being to spray small amounts of water onto the internal surfaces and thereby keep them clean. This technique has been found to be totally satisfactory. The period between boil-outs may be extended, but this does not eliminate the problem of scaling-up on the heating surfaces of the pan, which then dictate that the pan be taken off for cleaning.

On stopping and emptying the pan, the side and bottom internal surfaces of the pan have been inspected for encrustation or build-up. These surfaces have been found to be quite clean. This confirms the conclusion from tracer tests that the shape of the pan is such that no static regions of massecuite exist in the pan.

Conclusions

The use of continuous pan boiling for all grades of massecuites has been proved to be a practical proposition in raw sugar factories. This brings with it some significant benefits compared with a batch process, so that in the Tongaat-Hulett Sugar mills, all future pans will be continuous in operation.

The problems which have previously retarded the change from batch to continuous operations, namely encrustation and the production of a wider range of crystal sizes, have been overcome or effectively dealt with.

The benefits of this type of continuous pan, as far as thermal economy is concerned, can be considerable. In the first instance, lower quality vapours can be used in the calandria, which makes the re-use of low quality heat possible. In addition, the steadier operation of the whole pan floor contributes to improved thermal economy.

At present, batch pans are required to produce the seed for feeding to continuous pans. The next step will be to dispense with this batch operation as well. In this respect, the developments in the beet sugar industry will be watched with interest.

REFERENCES

1. Austmeyer, KE (1982). Die kontinuierliche Kristallisation der Saccharose aus heutiger Sicht. *Zuckerind* 107: 401–414.
2. Graham, WS & Radford, DJ (1977). A Preliminary Report on a Continuous 'C' Pan. *Proc SA Sug Technol Ass* 51: 107.
3. Hoekstra, RG (1985). Programme for Simulating & Evaluating a Continuous 'A' Sugar Pan. *Proc SA Sug Technol Ass* 59: 48–57.
4. Julienne, LMSA & Munsammy, S (1981). Assessment of the Gledhow & Tongaat Fives-Cail Babcock Continuous Pans *Proc SA Sug Technol Ass* 55: 79–82.
5. Kruger, GPN (1983). Continuous 'A' Boiling Trial at Maidstone Sugar Factory. *Proc SA Sug Technol Ass* 57: 46–51.
6. Matthesius, GA, Graham, WS & Pillay, JV (1978). An Application of the Fractional Factorial Experiment to Continuous Pan Boiling. *Proc SA Sug Technol Ass* 52: 89–92.
7. Munsammy, S (1982). The Re-Assessment of the Fives-Cail Babcock Continuous 'C' Pan at Gledhow & Preliminary Report on the Fives-Cail Babcock Continuous 'B' Pan at Illovo. *SMRI Tech Rep.* No. 1 315.
8. Rein, PW Cox, MGS & Love, DJ (1985). Analysis of Crystal Residence Time Distribution & Size Distribution in Continuous Boiling Vacuum Pans. *Proc SA Sug Technol Ass* 59: 58–67.
9. Rein, PW (1984). Advances in Sugar Crystallisation & Massecuite Handling using Continuous Pans. *Repts Hawaiian Sugar Tech Conf.*
10. Riviere, M (1982). Personal Communication, Beaufonds, Reunion.
11. Rouillard, A (1985). Massecuite Boiling. *Proc SA Sug Technol Ass* 59: 43–47.