CONTINUOUS 'A' PAN BOILING TRIAL AT MAIDSTONE SUGAR FACTORY

By G. P. N. KRUGER
Hulett Sugar Limited, Maidstone

Abstract

The new continuous pan at Maidstone which was designed for boiling 'B' massecuite was used for 'A' massecuite for the last five weeks of the 1982/83 season. The pan performed well and the success of the trial led to the decision to install continuous 'A' pans at the new Felixton II mill. Further 'A' boilings in the Maidstone pan are planned for the 1983/84 season.

Introduction

The advantages of continuous pans are well known.[1] Continuous pans for boiling 'B' and 'C' massecuites are used in several factories. It is a logical step to look at a fully continuous boiling house for the future, particularly in the case of a new mill. The construction of the new mill at Felixton prompted such a look at a fully continuous boiling house.

Continuous 'A' pan boiling was tried at Maidstone in 1977 in the 64 m³ Fives-Cail Babcock (FCB) pan.[2] The pan was installed to boil 'C' massecuite and is described in detail by Graham and Radford.[1] The trial showed that continuous 'A' pan boiling is feasible. False grain and high fines in the sugar were attributed to the seed pump being too small, resulting in low crystal content. Encrustation of sugar on unheated surfaces and the appearance of lumps in the massecuite were also identified as problems.

In 1981 experimental work on continuous 'A' pan boiling was carried out by Hulett Sugar technical staff at Amatikulu on a batch pan which was converted into a continuous pan by dividing it into six compartments. Severe problems with sugar build-up on the calandria tubes and below the calandria meant that the pan could not be run for periods of longer than six days. The introduction of jigger steam on an automatic cyclical timer helped to alleviate this problem. Problems were also encountered in preparing uniform seed for the pan and it was observed that seed quality and quantity were very important factors in producing good quality 'A' massecuite.

Although the results of the Amatikulu trial were not encouraging Hulett Sugar staff visited Reunion to inspect two factories operating continuous 'A' pans of the FCB design. Both these pans had been commissioned at the start of the 1982 season. Sugar encrustation did not seem to be a serious problem, although one factory had experienced lump formation. The pans had run for seven and eight weeks respectively without being emptied or cleaned. However it should be noted that massecuite brixes and viscosities tend to be lower in Reunion than in South Africa. Both factories used conductivity control which was performing satisfactorily. At the time of the visit, the pans had only one conductivity probe for every four compartments.

The work on the FCB pan at Maidstone and on the Amatikulu pan highlighted a number of potentially serious problems while indicating, along with the observations from Reunion, that continuous 'A' pan boiling warranted further investigation. It was essential that further data be collected before a decision in favour of continuous 'A' pans for Felixton II could be made. It was therefore decided to run trials on the new Maidstone pan in view of its excellent performance achieved with 'B' and 'C' massecuite.

Description of the Pan

The pan was installed during the 1982/83 season and was designed to boil all the 'B' massecuite produced by the factory at 400-450 tons of cane per hour.

The pan consists of a horizontal vessel with a working volume of 110 m³. It is divided into 12 compartments. Seed is pumped into the first compartment and the massecuite flows along one side of the pan and then back along the other side. (See Figure 1). Massecuite passes from one compartment to the

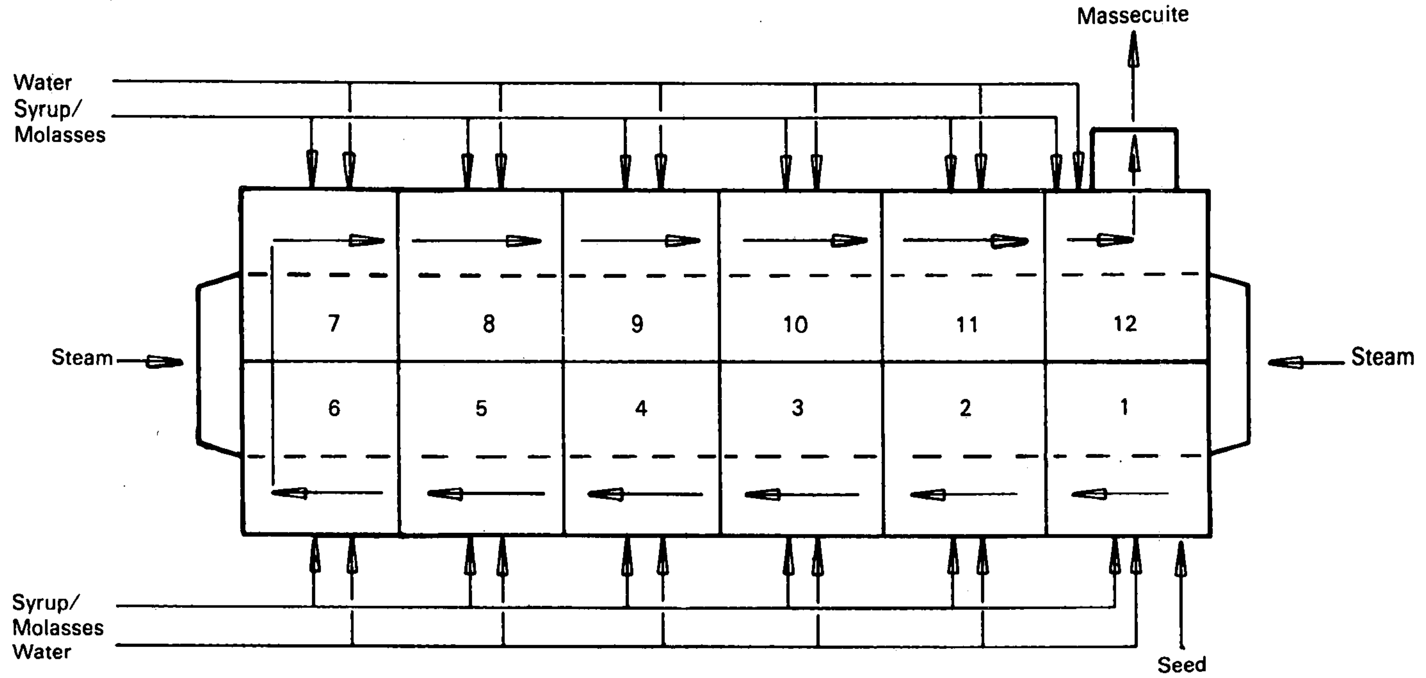

FIGURE 1 Pan layout

next via a 'postbox' type chute. Massecuite leaves the final compartment over an adjustable weir which allows for variation in the head of massecuite above the calandria. Each compartment has a facility to feed molasses/syrup or water.

The pan has a tubular calandria with a heating surface of 1106 m^2. The tubes are 1500 mm long and have a diameter of 100 mm. The calandria has a partition in the centre and steam is fed from each end of the pan. The pan is run on vapour one (50 kPa gauge). Jigger steam is provided to each compartment and can be opened or closed to the individual compartments. Sample points are located on each compartment. Sight glasses on the top of the pan provide good visibility in the pan.

Pan Control

The pan is fitted with three-term controllers for pan and calandria pressure control. The pan pressure is controlled by absolute pressure control. Brix (strictly supersaturation) control is by means of conductivity. Each compartment is fitted with a pair of conductivity probes. These send signals to Plastomatic on/off controllers which operate open/close, pneumatically-activated butterfly valves on the syrup/water feed to each compartment. The seed flowrate is adjusted by varying the speed of the seed pumps.

A Gem 80 microcomputer monitors the absolute pressure, calandria pressure and compartment conductivities and displays these on a colour graphics display. In addition the absolute pressure, calandria pressure and condensate flowrates are recorded by chart recorders. For the purpose of the 'A' boiling trial a twelve point recorder was hooked up to give a continuous recording of each compartment's conductivity. This feature turned out to be extremely useful and will be retained for normal pan operation.

Outline of Trial Period

The continuous 'A' pan boiling trial was started on 4 January 1983 and ran until 4 February 1983. During this period the pan was on range for 21 days, after which it was stopped, emptied and boiled out with water. It was then put back on range for another 9 days before being stopped at the end of the season. Unfortunately the factory throughput was unusually low and erratic during the trial period due to various problems, including cane shortage.

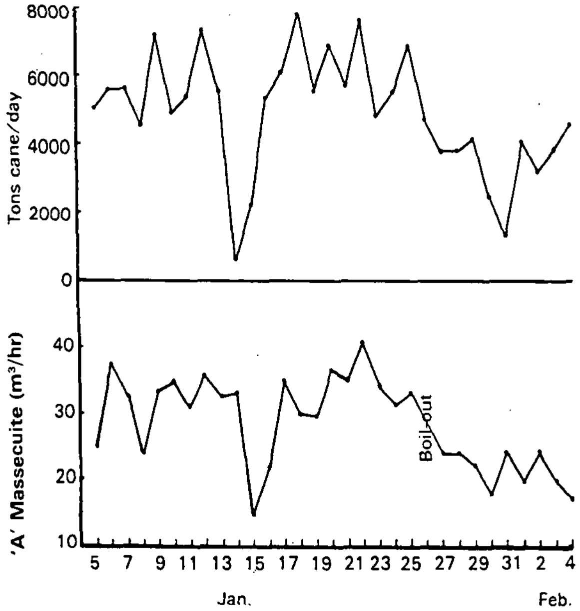

FIGURE 2 Factory throughput and massecuite throughput of continuous pan.

The factory cane throughput and massecuite production rate of the continuous pan are shown in Figure 2. The pan handled most of the 'A' massecuite throughput of the factory during the trial period but a few batch pans were struck at the beginning and the end of the trial, while two batch pans per day (28 m^3 per strike) were struck during the period 19–23 January.

Effects on Factory Performance

Obviously the effect of continuous 'A' pan boiling on factory performance is of prime importance. Since the continuous pan handled almost all of the 'A' massecuite processed at Maidstone during the trial period, the effect of continuous 'A' boiling may be assessed by looking at factory results for this period.

Sugar Quality

(1) *Pol*

Generally the pol of sugar produced during the trial period was above 99,30. It was found soon after the start of the trial that the wash water on the 'A' centrifugals could be reduced as the sugar pol had increased to 99,60. From Figure 3 it can be seen that on only three days did the pol of the sugar drop below 99,30.

(2) *Moisture*

The percentage moisture of the sugar was between 0,06 and 0,12 for the duration of the trial. At no stage did the moisture content of the sugar exceed the VHP specification.

(3) *Starch*

The starch content of the sugar did not exceed the VHP specification during the trial period.

(4) *Colour*

High sugar colour has been a persistent problem at Maidstone for some years. Figure 4 shows weekly colour as reported by the Sugar Terminal. Although it is difficult to draw definite conclusions from this data it is encouraging,

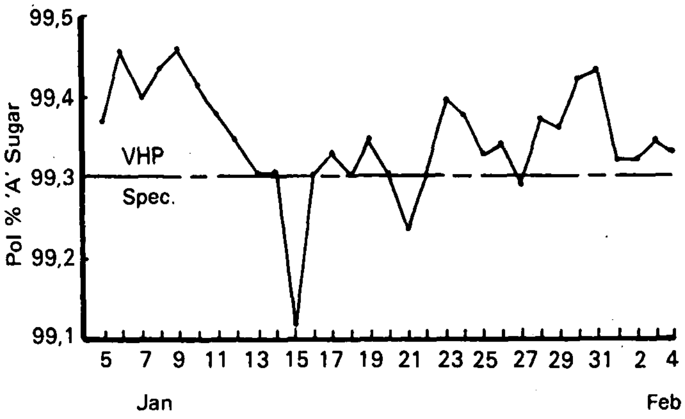

FIGURE 3 Pol of 'A' sugar for trial period.

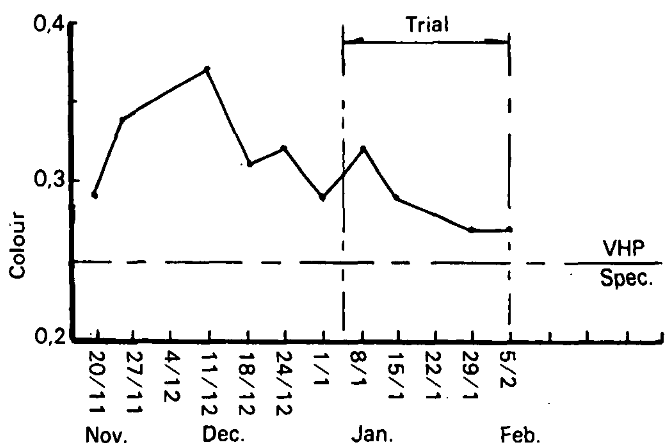

FIGURE 4 Colour of 'A' sugar at 560 nm (weekly figures).

since colour was decreasing during a period when it would normally be expected to be increasing.

(5) *Fines*

The percentage of fines (grain passing through a 28 mesh screen) in the sugar produced in the trial period is shown in Figure 5. This data comes from mill laboratory analyses of 24 hour composite samples. The samples were composited from 8 am to 8 am and dated with the second day's date.

Visually the sugar was of a good quality throughout the trial.

A-Massecuite Quality

(1) *Brix*

The 'A' massecuite analyses for the trial period are shown in Figure 6. For the early portion of the trial the brix was rather low. During this period various design data was collected and a general 'feel' for boiling 'A' massecuite in the pan was developed. From 23 January attention was given to increasing the 'A' massecuite brix.

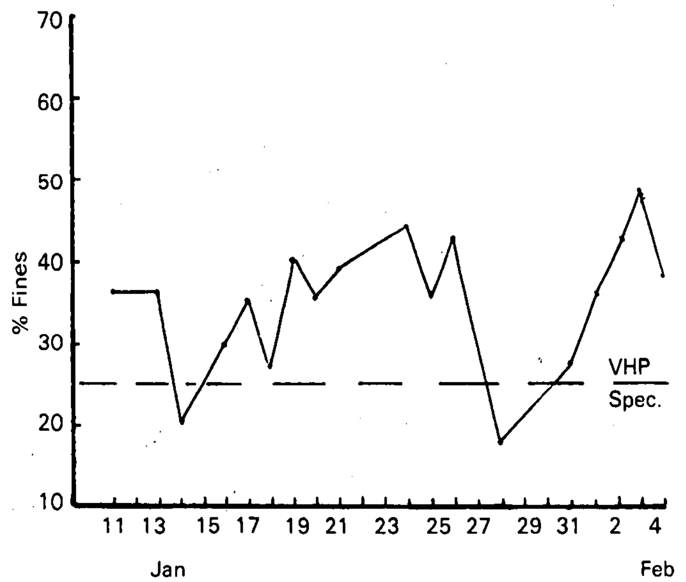

FIGURE 5 % Fines in 'A' sugar.

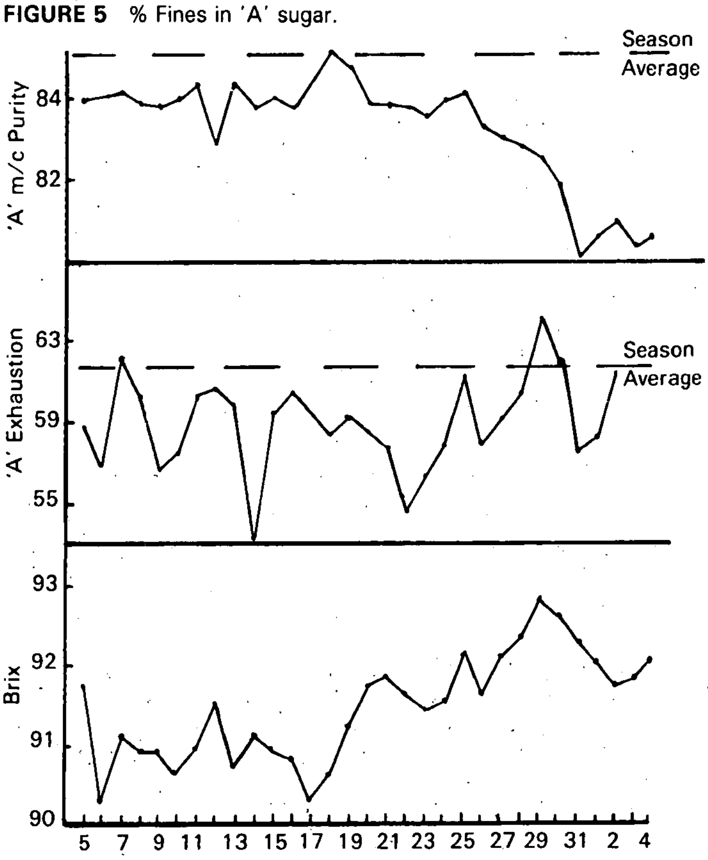

FIGURE 6 'A' massecuite data.

(2) *'A' Exhaustion*

'A' exhaustion for the trial period is plotted in Figure 6. These figures compare favourably with the season average for Maidstone which has limited 'A' crystalliser capacity. The exhaustion for January (continuous pan) was 58,7 which is significantly higher than for December (batch pans) at 55,5. This is most encouraging since it would be expected that 'A' exhaustion would be dropping at this stage of the season. Comparison of the brix and exhaustion curves suggests a possible correlation between increasing brix and increasing exhaustion.

(3) *Purity*

The purity of the 'A' massecuite during the trial period is shown in Figure 6. It can be seen that the purity was significantly lower than the season average.

Discussion

The trial has led to important observations in a number of areas. In terms of sugar quality for export, the fines content is important, while from an operating point of view, brix control, sugar encrustation and massecuite circulation are areas of interest.

(1) *Fines*

It is clear from the results that reduction of the fines content of the sugar produced by the continuous pan constitutes the only major problem in meeting the VHP sugar specification. A number of factors must be considered when looking at the fines problem.

(a) *Crystal Residence Time*

It has been generally assumed that the spread in crystal residence time in a continuous pan would lead to a wide size distribution in the product sugar, resulting in a problem in meeting the VHP fines specification.[3] The spread in crystal residence times depends on the flow characteristics of the pan which is a function of pan design. While perfect plug flow is ideal, such a condition is not possible in practice. A tracer test carried out by the SMRI[4] on the pan during the trial showed that it gave a much closer approach to plug flow than pans of the FCB design. The test showed the pan to be equivalent to about 18 stirred tanks in series. This means each compartment is equivalent to 1½ perfectly mixed tanks in series. This is significantly better than the results reported for FCB pans which gave 9 tanks in series with fourteen compartments.[3] Thus the crystal residence time distribution for the Maidstone pan is excellent.

(b) *Seed Crystal Size*

From an operating point of view it became clear during the trial that two of the critical parameters in obtaining good sugar quality are the seed quality and quantity. The fines content of 'A' sugar is closely related to the average grain size, as can be seen in Figure 7 which shows that provided the specific grain size (SGS) exceeds 0,66 the fines content will be below 25%. Thus, in considering fines the average grain size must be taken into account.

The coefficient of variation (CV), which is the ratio of standard deviation to average grain size, is more useful here as it is a measure of the crystal size distribution. The lower the value the closer the crystals are to being completely uniform. Figure 8 gives the CV's of seed and product massecuite on various days during the trial. These results show the strong relationship between the crystal size distribution of the seed and the product massecuite. It is interesting to note that the continuous pan gave a CV improvement of about 6,5 units from seed to massecuite, which compares favourably with CV improvements obtained in batch pans. This highlights the performance of the pan as compared to the FCB design, which gives a worsening (increase) in CV of between 0 and 3 units.

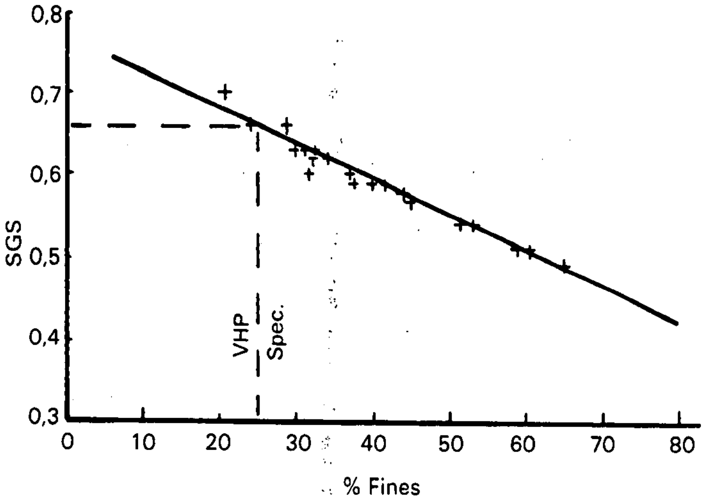

FIGURE 7 % Fines vs SGS for 'A' sugar produced by the continuous pan.

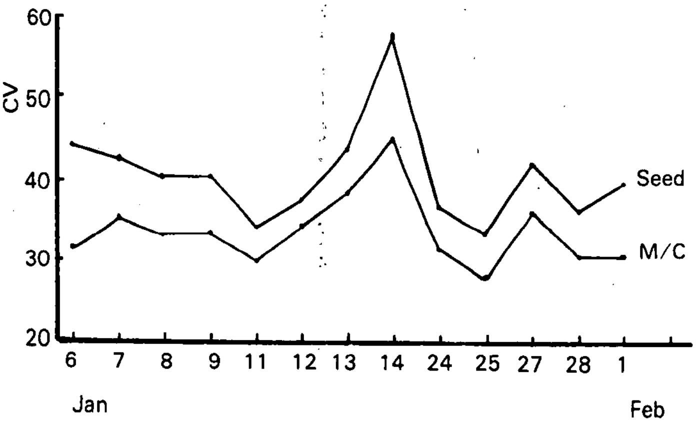

FIGURE 8 CV of seed and massecuite.

The SGS of the seed to the pan was 0,37 at the start of the trial. This was increased to 0,44 after a few days and later to 0,46 for the second half of the trial period.

(c) *Seed Rate*

In order to bring the fines content of the sugar down it is essential to have the correct quantity of crystal present in the pan. Too high a seed rate will result in reduced residence times and thus less growth per crystal leading to a lower SGS in the final massecuite. Too low a seed rate leads to a low crystal content in the pan which may result in false grain. From an operating point of view the problem lies in regulating the flow of seed in relation to the massecuite production rate. During the trial the massecuite to seed ratio varied from 4,6 to 1 down to 1,5 to 1.

At the start of the trial a simple approach was adopted. If 6 or more compartments were running on syrup feed, two seed pumps were run at the same fixed speed. If less than 6 compartments were running on syrup only one seed pump was run at the same speed as when two pumps were running. At all stages the number of compartments on syrup feed was determined by the syrup tank level. It soon became apparent that a more sophisticated approach was required. A schedule was drawn up relating seed pump speed settings to the number of compartments on syrup. Despite this the massecuite to seed ratio varied unsatisfactorily. For future trials it is planned to use a syrup flowmeter to maintain a constant ratio between seed and syrup flow rates to the pan.

(2) *False Grain*

False grain formation did not pose a serious problem in boiling 'A' massecuite in the continuous pan. When it did occur it was relatively easy to wash it out. The washing out procedure was the same as for batch pans with each compartment being dealt with separately. It was found that there was little point in washing out false grain if it appeared only in the last few compartments as it soon disappeared. At no stage of the trial did false grain in the massecuite have any serious effect on 'A' curing although it would have contributed to an increase in fines. It was found that running the first compartment on water to 'bring the grain together' helped to reduce false grain formation.

(3) *Brix Control*

One of the most important questions the trial was intended to resolve was whether conductivity control would be adequate for control of brix on 'A' massecuite. From the experience gained from the trial the answer is a qualified yes.

Control of each compartment in the pan at a set conductivity was on the whole excellent. The pan could be set up to give a conductivity profile which would hold steady for many hours. The conductivity probes had to be cleaned once per shift. This was done by actually pulling the probes out of the pan and rubbing them clean with a cloth. Steaming the probes in situ did not clean them adequately. It was found that a thin white deposit tended to form on the probes if they were not cleaned regularly. If this scale was allowed to build up too much the conductivity tended to drop indicating to the controller that the compartment was getting too tight. As a result the controller would open more feed and the compartment would run too slack.

The problem of controlling the brix profile in the pan is the changing relationship between conductivity and brix. Figure 9 shows a plot of conductivity against brix for compartment 11 for data collected over the last few days of the trial. It is clear that for any value of conductivity the brix can vary by as much as 1,5 units with changing massecuite characteristics and crystal content. This means that it is impossible, using conductivity, to set an accurate brix

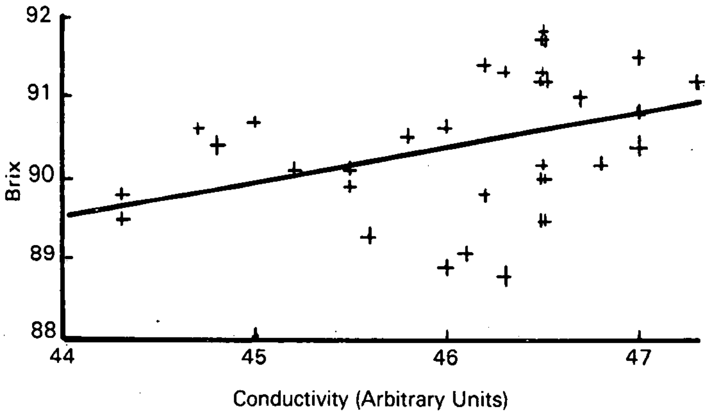

FIGURE 9 The conductivity-brix relationship.

profile and expect it to remain unchanged for any length of time. However, experience showed that it was possible to set an approximate brix profile which, with frequent attention from the operator, could be adequately maintained.

The brix profile which was aimed for is shown in Figure 10. This profile shape originated from the work done at Amatikulu. An example of the actual brix profile in the pan is also shown in Figure 10. This profile was built up from analyses of brix in various compartments over a 24 hour period.

Owing to the problems encountered with the brix-conductivity relationship and the effect of scaling of the probes, a start was made on alternative feed control systems. A radio frequency capacitance probe was installed in compartment 11. Results from this system looked promising and further tests are planned. Further work on conductivity control is also planned.

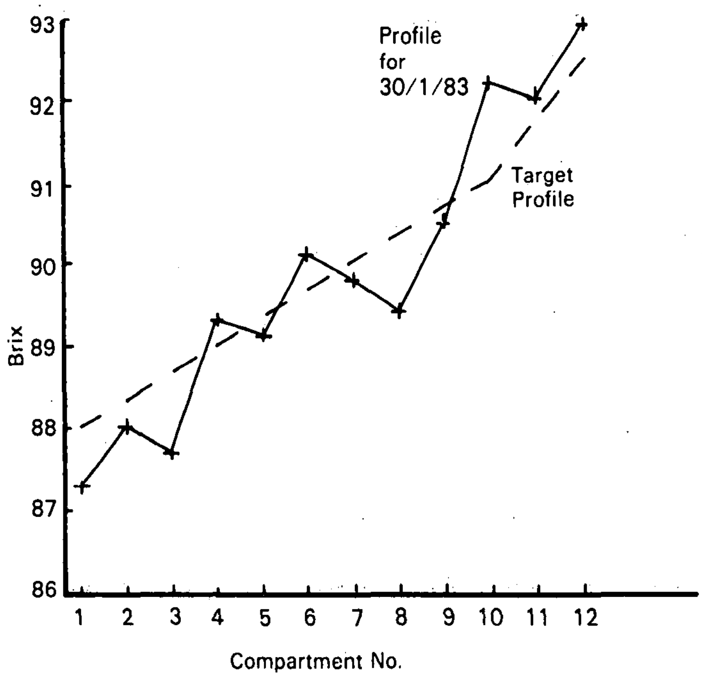

FIGURE 10 Brix profile.

(4) *Scaling and Encrustation*

One of the major problems of continuous pan boiling is sugar encrustation and scaling of the tubes and baffle plates in the pan.[2, 5, 6] This can cause tube blockage, a serious drop in evaporation rate and lumps in the massecuite which damage centrifugal screens and block pipes.

(a) *Evaporation Rates*

The pan was run for 21 days on 'A' massecuite before it was stopped and emptied. During the first 14 days the brix was low and the steam pressure was about 0 kPa gauge. The evaporation rate remained between 23 and 29 kg/h m.^{2} No drop in evaporation rate due to sugar encrustation or scaling was apparent. During the last 7 days of this period the massecuite brix was increased and the evaporation rate dropped to as low as 12 kg/h m^2 on 25 January when the product massecuite brix was in excess of 93 for a few hours. The steam pressure had been increased to 14 kPa gauge. It was decided to empty the pan and boil it out with water. Prior to the boil-out each compartment was inspected through the sight glass for visible tube blockage and encrustation of the baffles. Unfortunately there was not time to allow the pan to cool down sufficiently for an internal inspection. After the boil-out the pan was run for 9 days at higher brix. The steam pressure remained at 0 kPa gauge for the first 6 days and was raised to 4 kPa gauge over the last three days. The evaporation rate ranged from 24 to 32 kg/h m.^{2} After this period the pan was emptied, cooled and each compartment was carefully inspected. The results of the two inspections are discussed below.

(b) *Sugar Encrustation of the Baffles*

The work at Maidstone[2] and Amatikulu showed that sugar encrustation on unheated surfaces was a problem. The breaking away of this encrusted sugar layer was identified as the probable source of lumps in the massecuite. Various methods to prevent sugar encrustation on the baffles between compartments were looked at. Test patches of plastic coatings and epoxy paint were placed on the baffles in compartments 10 and 11. These were intended to provide a non-stick surface. Water sprays were positioned in compartments 9 - 12 to deliver a fine spray onto the baffles. It was found that the plastic coatings were fairly effective in preventing sugar build-up. However problems were encountered in keeping the coatings attached to the plates. The water sprays did an excellent job of keeping the baffles clear of sugar build-up and it was concluded that this would be the cheapest and most effective way of preventing encrustation on the unheated surfaces.

In the first 8 compartments sugar encrustation on the baffles did occur. The first inspection prior to the boil-out showed sugar encrustation on the lower portion of the baffles. It was however difficult to see how heavy the build-up was. The second inspection showed that heavy encrustation had occurred on the baffle plates. It appeared that a layer of sugar about 5 mm thick would build up in the centre of the baffles and then break away. In the corners of the compartments where there are ladder rungs for access between compartments the encrustation had not broken away. In compartment 4 three distinct layers of encrustation could be seen.

It is interesting to note that despite the evidence that layers of encrusted sugar were breaking away from the baffle plates no sign of any lumps was found in the massecuite at any stage of the trial.

TABLE 1

Tube Blockages

Compartment No.	% Tubes Blocked	
	First Inspection: 21 Days	Second Inspection: 9 Days
1	Nil	Nil
2	Nil	Nil
3	4	6
4	<1	6
5	51	1
6	13	1
7	4	Nil
8	6	2
9	20	1
10	3	<1
11	Nil	Nil
12	4	1

(c) *Tube Blockages*

The percentage of blocked tubes found in both inspections is given in Table 1. The high proportion of blocked tubes in compartment 5 seen in the first inspection cannot be explained at this stage. It may have been due to a large plate of encrusted sugar falling from the baffle or it may have been bridging of the massecuite across the tubes on striking the pan. The data given in Table 1 indicates that there is no brix effect and the blocking of tubes appears to be fairly random. The blocked tubes cleared easily with a water boil-out.

From these experiences it appears that scaling and sugar encrustation in a pan of this design does not constitute a major problem when boiling 'A' massecuite, and a routine boil-out with water should be sufficient to prevent excessive sugar build-up.

An interesting event in the trial was a 22 hour factory stop for no cane on 14–15 January. A decision was taken to simply slacken the pan and stop, without emptying it. Despite the fact that the pan was not lagged and cooling was significant it started very easily and the evaporation rate returned to 27 $kg/h\ m^2$

(5) *Massecuite Circulation*

Good massecuite circulation is of prime importance in maintaining high evaporation rates and preventing sugar build-up in the tubes. During the period in which the pan boiled at brixes of less than 92, circulation in all compartments was good. However, once the brix was raised above 92 the circulation in the last few compartments, particularly number 12, deteriorated. Jigger steam was used in compartment 12 at about -20kPa gauge. Although this did help, the major problem lay in the fact that the pan outlet on compartment 12 allowed by-passing from compartment 11 to the discharge, resulting in compartment 12 sitting stagnant. This will be corrected before future trials by means of a baffle.

A problem which developed at brixes in excess of 92,5 was a hydraulic gradient in the pan. At these brix levels the 'postbox' chutes between the last few compartments became a restriction to flow. A massecuite head of more than 1000 mm above the calandria developed in the first few compartments when the discharge weir was set to give a head of 300 mm above the calandria in the last compartment. This had serious consequences when the last few compartments were slackened off, as a flood of massecuite pushed through the pan. At low brix the hydraulic gradient in the pan is so low that it is difficult to see any difference in level between the first and last compartments. The chutes between the last few compartments will be enlarged before future trials.

(6) *Vacuum Control*

Vacuum control was not entirely satisfactory during the trial as the pan's condenser (designed for 'B' boilings) is marginal in size when boiling 'A' massecuite. The pan was generally run between 16 and 18 kPa absolute.

Conclusion

The continuous 'A' massecuite boiling trial has shown that the process is entirely feasible and that it has great potential for improving pan floor operations and factory performance. A number of important questions have been resolved:-

(1) The continuous pan can consistently produce sugar meeting with VHP specification with the exception of the fines specification. However, the fines specification was met for limited periods during the trial and it is felt that with further operating experience and improved control this problem will be solved.

(2) False grain formation is not a major problem.

(3) Conductivity can be used for control of brix profiles in continuous 'A' pans.

(4) Scaling and encrustation are not a major problem.

The results achieved in the initial trials on 'A' massecuite on the new Maidstone pan produced significantly better results in several respects than achieved in other continuous 'A' pans in South Africa. This is attributable to the pan design, control system and operator experience from continuous 'B' and 'C' boiling.

The success of the trial has led to the decision to install continuous 'A' pans in the new mill at Felixton. This mill will have the first fully continuous boiling house in South Africa.

Acknowledgements

This work is the result of a concentrated effort by a number of people. I should like to thank those staff of TMD, R & D and Maidstone Mill involved with the trial for all their assistance.

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