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# CONTINUOUS BOILING OF LOW GRADE MASSECUITES

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## Introduction

This paper outlines the work carried out so far in investigating the possibility of introducing continuous boiling techniques to the pan stage.

The implementation of the practice of continuous sugar boiling has been relatively slow in the world raw sugar industry. In recent years, however, several publications relating to the design and performance of various systems of continuous sugar boiling have appeared, Bennett (1969), Windal (1971), Barkow *et al* (1971), and Luce (1970). The numerous advantages of the continuous process are offset to some extent by some disadvantages, which must be minimized before the continuous process becomes fully accepted. These advantages and disadvantages have been listed previously, Windal (1971) and Wright (1974).

## Aspects of Continuous Operation

In a continuous boiling scheme, seed crystals are metered to the unit at a controlled addition rate, and acceptable product massecuite withdrawn continuously.

Continuous boiling schemes have so far been introduced into several European refineries and experimentally in a few beet raw sugar factories. The advantages claimed are the usual economies of continuous flow operations. The major disadvantage in such a scheme as far as Queensland raw sugar mills are concerned is that the product crystal distribution is much more spread than that produced in batch units (CVn of the order of 0.4 as reported in the European units).

The system considered most likely to be successful here is a vessel which is subdivided into a series of compartments through which massecuite flows progressively from the first to the final section. This arrangement would provide a narrower spread of residence times for the crystals. However, theoretical considerations indicate that for a massecuite produced from a seed inlet of fine slurry crystals, a minimum of 25 such compartments in series would still be required to yield a crystal product with a coefficient of variation of 0.20 (comparable with present batch production). With such a large number of compartments one would expect problems in the control of density in each section, but indications from overseas show control at a few intermediate cells plus conductivity control on the final cell is sufficient. The number of cells required could be reduced dramatically if some simple means could be developed to classify the crystals at some intermediate stage(s) in the system, with the fines component recycled back for further growth. But this is not easily implemented, because the high viscosities of saturated sugar syrups and massecuites prevent techniques successful in other particle systems from being applied.

These investigations to date have concentrated on continuous boiling of low grade material because the size specification here is less critical then for shipment sugar. Also, the adoption of continuous low grade boiling together with continuous cooling crystallizers and continuous low grade fugals would result in a much more controllable steady flow in the recovery station, which should allow for better factory performance.

## Work Undertaken to Date

Continuous low grade boiling tests were conducted in the horizontal pan at Marian mill during the 1971 and 1972 seasons Wright (1974). During this time, several features which would be desirable to incorporate into a design for a continuous

unit became obvious and, at the end of these tests, it appeared that no significant improvement in performance could be expected from the unit without incorporating these features.

The tests conducted on this unit indicated that desirable features for a low grade continuous pan are:

(a) high heating surface/volume ratio to provide good circulation and uniform mixing in each compartment. It was observed during the tests that circulation in the pan appeared much slower than it had been when the pan was used for batch boiling—presumably caused by the drag on the fluid from the dividing bulkheads. This is particularly important for the final compartment, where massecuite is at the dropping Brix and circulation slow.

(b) boiling level no more than 0.6 metres above the top of the calandria. The constant level of operation in a continuous unit could then take full advantage of the high heating surface/volume ratio.

(c) multiple entry points for the molasses and water feed to each compartment to provide rapid intermixing with the contents.

## Rocky Point Tests—1973

At this stage an approach was made by Evans Deakin Industries suggesting a design for a single element which they were considering. The Institute agreed to test such an element of modified design as installed at Rocky Point during the 1973 season.

The pan with its tubed calandria has a heating surface/volume ratio of 9.9 $m^{-1}$, which is about twice that usual in batch pans. The design boiling level was 0.3 m above the back of the sloping top tube plate and, at this level, the capacity of the unit was 2.95 $m^3$. The de-entrainment system consisted of two sets of wedge bar screens arranged to deflect the vapour through two right angles before entering the vapour offtake pipe.

## Batch Trials

Initially, batch boiling tests were conducted in the unit to investigate the influence of the high heating surface/volume and low head design on the circulation, evaporation rate and entrainment levels of solids in the vapour. These were studied for different density massecuites, steam flows to the calandria and massecuite boiling levels, so that the complete range of operating conditions expected in a full scale continuous low grade pan was investigated. Circulation was studied by means of a small radio transmitter enclosed within a teflon ball which freely circulated within the massecuite. An aerial was mounted across the downtake, which recorded each full circulation cycle completed by the transmitter. These batch tests indicated:

(a) boiling in the pan was vigorous and indicated definite movement of massecuite in the direction of the circulation path.

(b) overall heat transfer coefficients based on the outside diameter of the tubes varied from 0.13 to 0.28 kW/$m^2$ °C. Comparable values on the Marian pan ranged from 0.34 kW/$m^2$ °C for light material at the start of a C strike to 0.07 kW/$m^2$ °C for material ready for pan drop. The test pan showed particularly good heat transfer to heavy materials.

(c) the wedge bar screen de-entrainment arrangement was unsuitable for a continuous installation because it became choked after a few hours operation.

## Continuous Tests—1973

Towards the end of the season, two continuous boiling runs were conducted, in which conditions closely resembled the final stage of operation of a full scale unit. Figure 1 shows a sketch of the equipment layout used for these tests.

Once the operation had steadied, a lithium tracer was added to the feed inlet and the residence time distribution of the product material determined by measuring the lithium concentration in the product material by atomic absorption techniques. Figure 2 shows the experimental residence time distribution obtained from one of these runs. This result shows very close agreement with the distribution expected from



a single perfectly mixed vessel of the same mean residence time. This indicated good mixing was achieved in the test unit, and conditions should therefore have been uniform throughout.

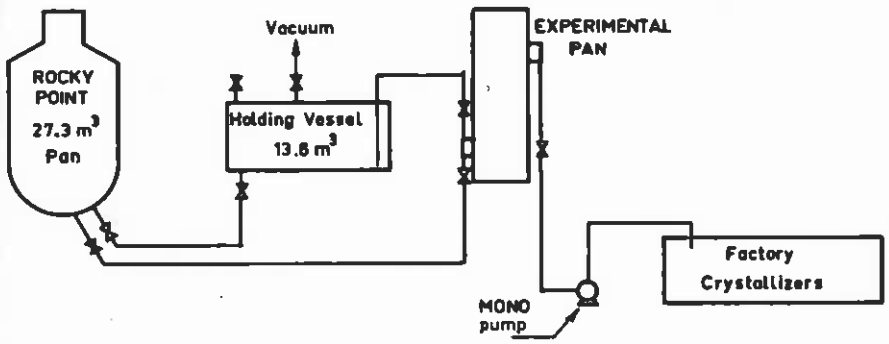


Fig. 1—Schematic layout for continuous boiling tests—1973.

In each of the two continuous runs the pan was boiled below its maximum evaporative capability. Throughput rates were 2.6 and 2.2 $m^3$/h and the Brix of the massecuite stream through the unit was increased by an average of 2.7 and 1.8 units, respectively, for the two runs. Product refractometer Brix averaged 94.9 and 96.0 units and appeared of good consistency for pan drop material.

As a result of the tests several minor modifications to the design were suggested, but it was considered the unit would perform favourably as a cell of a full scale continuous pan.

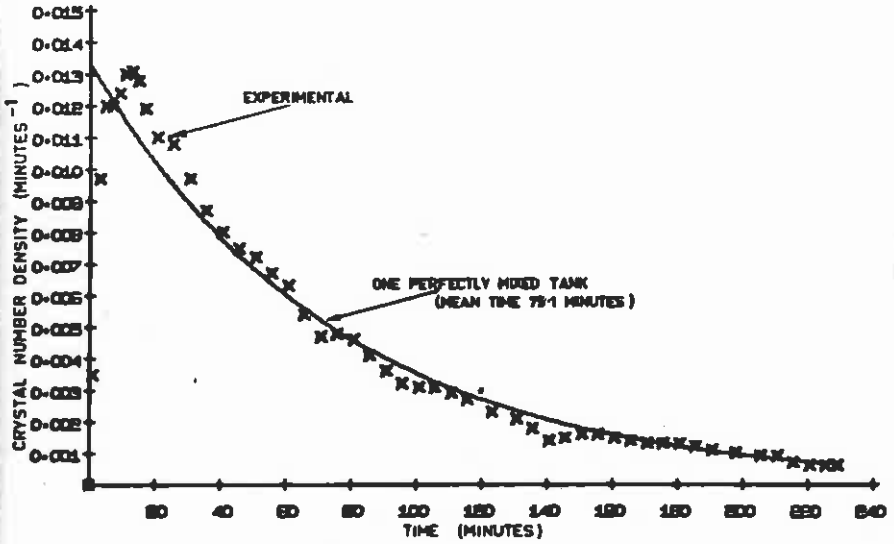


Fig. 2—Residence time distribution for one cell.

## Continuous Tests—1974

For tests in 1974, the horizontal pan from Marian mill, the unit tested in 1973, and two similar units were installed at the Rocky Point factory. The overall arrangement is shown in Figure 3. This arrangement, with compartmental volumes of

2.95 $m^3$, 3 × 3.3 $m^3$, and 2 × 3.0 $m^3$, was designed to handle the total low grade massecuite production for the mill. Seed material grown in the Rocky Point batch graining pan to about 180 $\mu$m size was metered to cell 1. Conductivity controllers regulated the "B" molasses feed to each cell. Product massecuite was pumped from cell 6 to factory crystallizers.

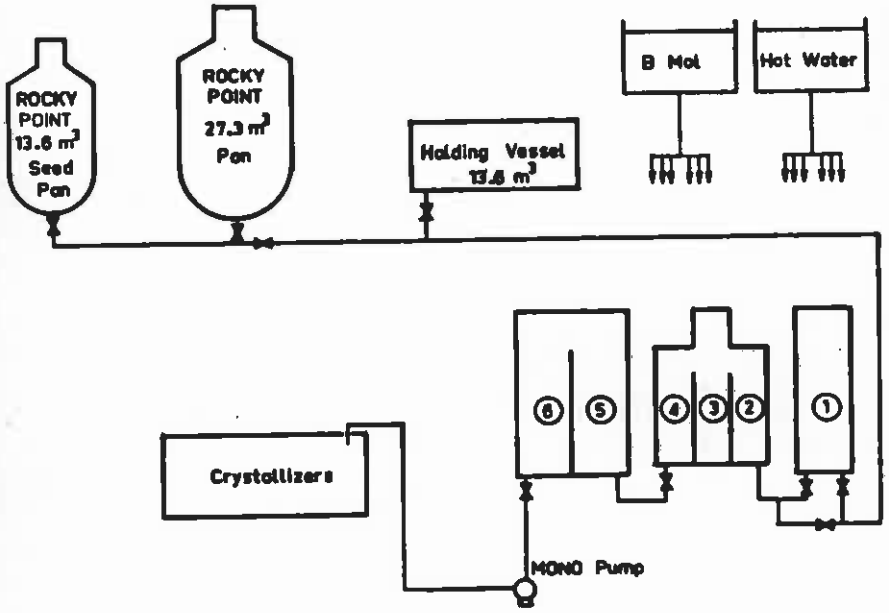


Fig. 3—Schematic layout for continuous boiling tests—1974.

Modifications to the original cell design included:

a) the "back-to-back" design of cells instead of separate individual cells as originally proposed,
b) installation of louvre entrainment arrestors,
c) improved multi-entry point feed distributors, and
d) positioning the pumpout line to pump directly from the bottom of the down-comer section.

The major problem encountered during the tests was pump failures to handle heavy massecuites and weaknesses in a friction disc variable speed drive unit.

Consequently, pumpout rates approaching 3.5 $m^3$/h production were only achieved for periods of 31, 41 and 17 hours. Other tests were conducted using a smaller pump with production rates of up to 2 $m^3$/h. The longest period of continuous operation was 95 hours and included periods of both high and low production rates. Cells 2, 3 and 4 appeared to be slowing down at the end of the period.

Start-up procedure involved the transference of seed to cells 2, 3 and 4 and boiling on with "B" molasses as soon as the heater plates were covered. Once the operating level was reached, the 4 to 5 cutover valve was opened, and the seed supply input transferred to cell 1, while continuing to boil on in cells 2-4. As soon as the calandrias in cells 1 and 5 were covered, boil on with "B" molasses was commenced. The 5 to 6 cutover was then opened and pumpout commenced as soon as operating conditions in cell 6 were reached. Pumpout was achieved approximately 5½ hours after startup.

Control points for conductivities in cells 1-4 were set to give conditions similar to that prevailing in the corresponding stages of a batch strike. Cell 5 was operated at a conductivity midway between that of cell 4 and the pan drop condition of cell 6.



Control loops included:

a) On-off conductivity controllers on cells 1 to 5.
b) Proportional conductivity controller on cell 6.
c) Vacuum controller.
d) Manual steam control.
e) Manual control on seed and pumpout rates.

Little operator intervention was required and, once operating, the whole set-up appeared to control itself under steady conditions. At times it was required to feed "B" molasses/water, or just water to cell 5, as well as cell 6 to maintain reasonable levels and/or "B" molasses/seed ratios. Even at the higher production rates, the operation of the pan was certainly below the evaporation limit and the only limiting factor was the pumpout rate. The exception was if the boiling level rose to the extent where cells 2 to 4 (Marian pan) slowed considerably as observed by Wright (1974).

The absence of lagging on the vessels would tend to promote fine grain formation, but this rarely occurred except following severe process disturbances, e.g., large vacuum fluctuations or sucking air from empty molasses tank.

Table 1A lists the operating conditions for high and low production rates, with Table 1B giving corresponding steam flows to cell units. It will be noted that at the lower pumpout rate, steam flows were kept at a high level, balance being maintained with "movement water". The seed flow to pumpout ratios averaged, in the case of the low production rates, 1:2.65, and 1:2.3 for the high production rates.

TABLE IA—Operating conditions

| Production level | Seed rate ($m^3$/h) | Product rate ($m^3$/h) | Viscosity (p @ 50°C) | Vacuum (kPa) |
|---|---|---|---|---|
| low | 0.717 | 1.761 | 780 | —87.3 |
| high | 1.444 | 3.301 | 800 | —87.3 |

TABLE IB—Steam flow rates

| Production level | Steam flow (kg/h) | | | |
|---|---|---|---|---|
| | Cell 1 | Cells 2-4 | Cell 5 | Cell 6 |
| low | 308 | 349 | 328 | 248 |
| high | 297 | 360 | 399 | 334 |

## Product Quality

Sampling points in the process streams allowed sampling of the "C" seed, "B" molasses, and massecuites from each cell unit. Massecuite samples were pressure filtered to obtain corresponding mother liquor, which permitted crystal contents for each cell to be calculated by a pol balance. The apparent purities reported in this paper are determined after an accurate 1:1 dilution, using the method recommended in Laboratory Manual for Queensland Sugar Mills, Anon (1970), for pol, and a refractometer for Brix. The refractometer Brix of pan products is normally lower than that determined by spindle, the difference varying with purity. Accordingly, the Brix values shown will be lower, and purity values inflated when compared with normal mill routine analyses.

Table II gives average values for three independent tests over the whole unit and shows changes in material Brix, purity, and crystal content (as per cent on massecuite) through the process.

It can be seen that a significant part of the heavy-up load was taken by cell 5 which, as mentioned elsewhere in this paper, operated often on molasses and water feed.

It should not be thought that the final massecuite Brix is the maximum achievable in the unit. Higher values were possible, and in fact obtained, but not maintained because of concomitant drastic reductions in pump-out rate, requiring steam and seed flows to be reduced to prevent pan levels building up. Thus, to gain meaningful values for evaporative capacity and production rate, it was necessary to operate with

a final mass Brix somewhat lower than desirable to achieve reasonable pump throughput.

As a guide to the operators, the chemical staff at Rocky Point mill analysed final product samples for Brix (26 analyses) and purity (13 analyses) by their normal method, giving an average spindle Brix of 97.0 (range 95.0-99.0) and apparent purity of 64.8 (range 63.5-66.0).

**TABLE II—Analyses of material from continuous unit**

| | Massecuite | | | Mother liquor | |
|---|---|---|---|---|---|
| | Refrac. Brix | App. purity | Crystal content | Refrac. Brix | App. purity |
| B mol | — | — | — | 78.6 | 65.7 |
| C seed | 87.9 | 67.8 | 14.5 | 85.7 | 61.6 |
| Cell 1 | 91.0 | 67.7 | 19.8 | 88.3 | 59.0 |
| 2 | 91.4 | 67.4 | 22.8 | 88.4 | 56.8 |
| 3 | 91.9 | 67.6 | 24.0 | 89.0 | 56.5 |
| 4 | 91.2 | 67.4 | 21.6 | 88.4 | 57.5 |
| 5 | 92.9 | 67.6 | 26.0 | 89.9 | 55.3 |
| 6 | 93.0 | 66.9 | 27.8 | 89.7 | 53.2 |

Photomicrographs of seed, final product, and material from some intermediate stages were obtained on a routine basis. Later, these were used to produce enlargements from which crystal size and dispersion were determined using a Zeiss particle size analyser. Table III shows mean sizes and coefficients of variation (CV) for seed and final massecuite, and for a limited number of tests on "A" sugar produced from magma derived from the continuous unit. The size dispersion of the "C" seed is typical of a good, uniform graining, and while this value increases through the strike, the final product coefficient of variation of 0.28 is acceptable as high-grade foundation material. When continuous fugals are used, with their associated crystal breakage, the advantages of a lower CV from batch compared with continuous strikes is largely lost, and in both cases extensive magma treatment would be required, either in the magma pan or in a classifier.

**TABLE III—Crystal size distribution analysis**

| Sample | Num mean (microns) | $CV_N$ | Mass mean (microns) | $CV_M$ |
|---|---|---|---|---|
| Seed | 172 | 0.21 | 196 | 0.19 |
| Product | 276 | 0.28 | 349 | 0.26 |
| "A" sugar | 814 | 0.30 | 1023 | 0.24 |

## Residence Time Study

Residence time distribution investigations of the crystals through cells 5 and 6 and through cells 1 to 6 were undertaken using a lithium tracer. The residence time distribution for the crystals leaving cell 6 was assumed to be the same as the lithium concentration distribution emerging from the system. The residence time distribution density function obtained from cells 1 to 6 and from cells 5 and 6 are shown in Figures 4 and 5, respectively. Theoretical residence time distributions for perfectly mixed cells of the same mean time as in each case are also plotted. From Figure 4 it is seen that the actual residence time distribution approaches that of a distribution from six perfectly mixed cells in series, although there is a certain peak displacement evident. This observation is in general agreement with previous residence time studies on continuous cells, Wright (1974). From Figure 5 it is seen that the residence time distribution over cells 5 and 6 alone corresponds best with that theoretically obtained from four perfectly mixed cells in series, though the match in curves is not good. A more complex analysis is required to get a better match. However, it can be said that these two cells behave better, in terms of approximation to a "plug flow" system, than would be expected from two perfectly mixed cells. This better performance is probably due to the internal baffling inserted by Evans Deakin designed to give a measure of plug flow in each cell, and these baffles can therefore be said to be beneficial to the flow pattern.



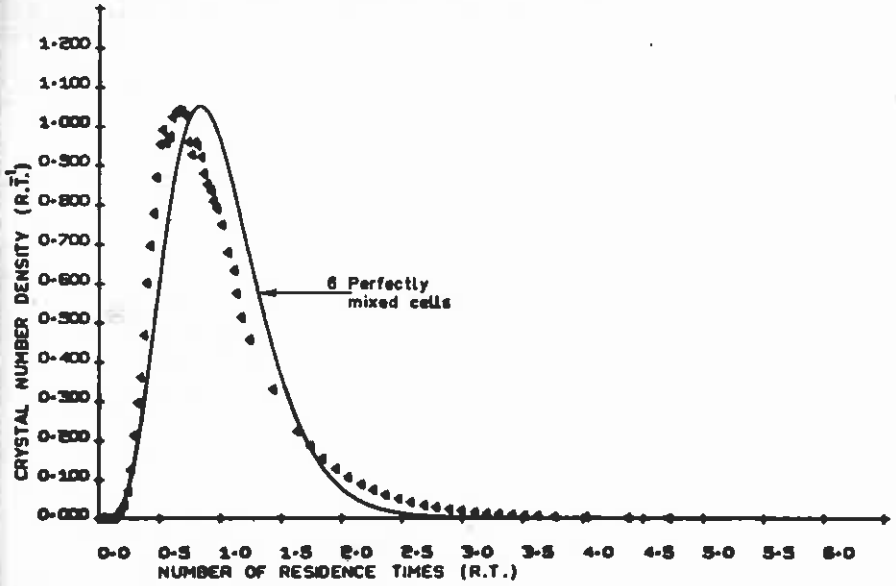


Fig. 4—Residence time distribution for cells 1 to 6.

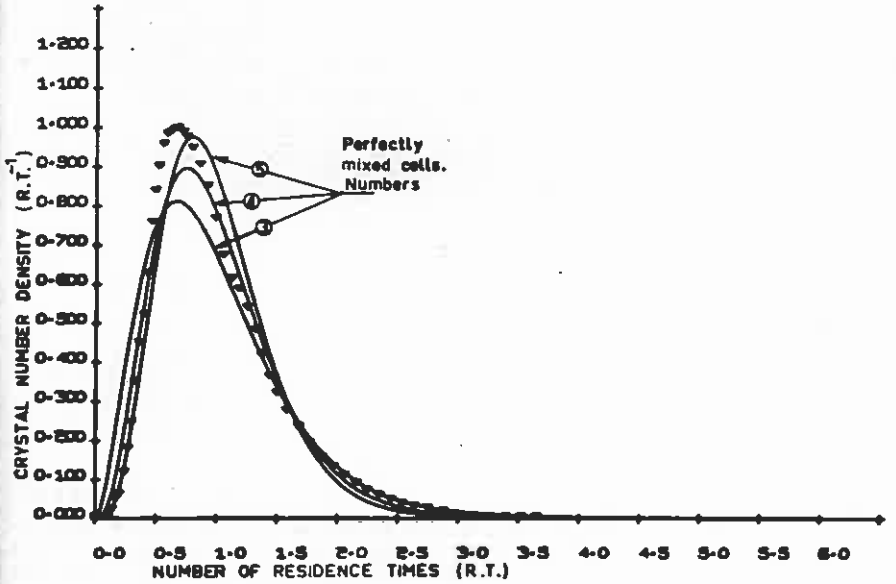


Fig. 5—Residence time distribution for cells 5 and 6 only.

## Conclusion

At this stage of the investigations the following points can be made:

a) The "C" sugar magma produced is comparable to that produced by batch boilings fugalled continuously.

b) The production rate achieved was equivalent to a batch unit of similar volume dropped on a 5.5 hour cycle. Higher pumpout rate capabilities will be required

refineries and mills, and these were borne in mind in writing the programme of work.

Massecuites were boiled simultaneously in No. 6 and No. 8 pans, using five different boiling techniques in an effort to produce massecuites from No. 6 pan of a quality equivalent to that obtained from No. 8 pan under natural circulation. No. 8 pan was boiled in the normal manner using constant conductivity feed control throughout these trials. Briefly these techniques were:

1. Using conductivity feed control, B molasses was boiled on at constant conductivity with a circulator speed of 60 rpm. During the tightening of the strike, the circulator speed was reduced to 45 rpm.
2. B molasses was boiled on at constant mobility at a circulator speed of 60 rpm with tightening at speeds of both 60 rpm and 45 rpm. The term mobility feed control means that the feeding of B molasses was controlled according to the load on the motor driving the circulator.

**TABLE I—Specifications for No. 6 and No. 8 pans at Victoria mill**

| Feature | No. 6 Pan | No. 8 Pan |
|---|---|---|
| Nominal capacity—tonnes | 100 | 100 |
| Optimum capacity—tonnes | 85 | 85 |
| Heating surface—$m^2$ | 442 | 416 |
| Type of heating surface | Calandria | Calandria |
| Massecuite height above calandria at dropping—m | 1.47 | 1.13 |
| Diameter of well—m | 1.98 | 2.44 |
| Diamter of pan at dropping level—m | 5.56 | 6.40 |
| Mechanical circulator design | Webre | |
| Diameter of circulator—m | 1.75 | |
| Power—kW | 71 (max) | |
| Speed—rpm | 0-70 | |

Techniques 3 and 4 involved boiling on B molasses at decreasing conductivity and mobility. A circulator speed of 60 rpm was used both for boiling on and tightening the massecuite. These latter two techniques gave a gradual tightening of the massecuite as the pan filled up. The fifth technique was similar to the fourth, except that the evaporation rate was reduced during final tightening.

In carrying out these trials, the following data were recorded: weight of footing, weight dropped, boiling time and fugal spin times. Samples of massecuite were were withdrawn for analysis and calculation of crystal percentage, pressure filter molasses purity, massecuite purity, impurity/water ratio and supersaturation ratio.

## Results

### *Comparison of Boiling Techniques*

The average values obtained in paired trials where the various different boiling techniques were employed, are shown in Tables II and III.

In all trials there appeared to be a significant gain in boiling rate in the mechanically-circulated pan. This was largely the result of a poor and erratic steam supply throughout the course of the trials. There were individual trial pairs where a good steam supply was available, and the improvement in boiling rate in No. 6 pan was of the order of only eight per cent. However, these trials did indicate the great benefits in maintaining good circulation when there were drops in steam pressure.

It was also found that in boiling very refractory material mechanical circulation was beneficial in maintaining satisfactory boiling rates, which could not be obtained under natural circulation even with good steam pressure.

It was not always possible to boil massecuites free of false grain in the naturally-circulated pan. However, whenever false grain was present in massecuites from No. 8 pan, its twin from No. 6 pan was as bad, and generally worse. None of the boiling techniques used gave consistently clean massecuites in the mechanically-circulated pan.

It is well known that false grain forms when the level of supersaturation in the mother liquor exceeds a certain value. The supersaturation ratio of the molasses



was measured at the time of dropping, and these values were consistently higher for mechanically-circulated massecuites. The pressure filtered molasses purity on dropping confirmed that massecuites from No. 6 pan were exhausted to a lesser extent, despite the fact that impurity/water ratios were comparable in both instances.

The fugalling quality of the mechanically-circulated massecuites was slightly poorer than the naturally-circulated ones. This, of course, was expected from the relative quantities of false grain present. It was interesting that there was no significant difference in molasses purity at the fugals from the trial pairs. This suggests that sufficient time was spent in the crystallizers to exhaust both massecuites in the trial pair to approximately the same level. That is, what was lost in exhaustion in the mechanically-circulated pan was fully recovered in the crystallizer.

### *CSR Refinery Experience*

In comparing low grade boiling practices in CSR mills and refineries, the most significant difference found was the crystal size in the C massecuite. CSR mills

**TABLE II—Averaged data for trials boiled with constant conductivity and constant mobility feed control**

| Boiling Techniques | Constant conductivity | | Constant mobility | |
|---|---|---|---|---|
| | No. 6 pan | No. 8 pan | No. 6 pan | No. 8 pan |
| Footing weight—tonnes | 50 | 50 | 50 | 50 |
| Weight dropped—tonnes | 85 | 85 | 85 | 85 |
| Total boiling time—$h_r$ | 3.5 | 5.5 | 3.9 | 5.7 |
| Massecuite true purity | 69.2 | 68.9 | 68.3 | 68.6 |
| Pressure filter molasses true purity on dropping | 48.3 | 45.3 | 48.2 | 45.6 |
| Purity drop massecuite to molasses | 20.9 | 23.6 | 20.1 | 22.8 |
| Percent crystal on dropping | 37.2 | 39.4 | 35.5 | 38.5 |
| Massecuite impurity/water ratio | 3.4 | 3.3 | 3.3 | 3.5 |
| Supersaturation ratio on dropping | 1.12 | 1.07 | 1.16 | 1.10 |
| Fugal spin times—m | | | | |
| ASEA fugals | 14 | 14 | 13 | 12 |
| Western States fugals | 9 | 7 | 8 | 7 |
| No. paired trials | 2 | | 5 | |

**TABLE III—Averaged data for trials boiled with decreasing conductivity and decreasing mobility feed control**

| Boiling techniques | Decreasing mobility | | Decreasing conductivity | | Decreasing conductivity & reduced evaporation during tightening | |
|---|---|---|---|---|---|---|
| | No. 6 | No. 8 | No. 6 | No. 8 | No. 6 | No. 8 |
| Footing weight—tonnes | 50 | 50 | 50 | 50 | 50 | 50 |
| Weight dropped—tonnes | 85 | 85 | 85 | 85 | 85 | 85 |
| Total boiling time—$h_r$ | 3.6 | 5.3 | 3.6 | 4.9 | 3.9 | 5.1 |
| Massecuite true purity | 68.0 | 67.8 | 68.9 | 69.3 | 69.2 | 69.1 |
| Pressure filter molasses true purity on dropping | 46.4 | 45.4 | 47.1 | 47.4 | 47.9 | 46.5 |
| Purity drop massecuite to molasses | 21.5 | 22.4 | 21.8 | 21.9 | 21.3 | 22.6 |
| Percent crystal on dropping | 36.6 | 37.6 | 37.7 | 38.0 | 37.0 | 38.5 |
| Massecuite impurity/water ratio on dropping | 3.4 | 3.4 | 3.3 | 3.2 | 3.3 | 3.3 |
| Supersaturation ratio on dropping | 1.13 | 1.06 | 1.18 | 1.00 | 1.13 | 1.09 |
| Fugal spin times—m | | | | | | |
| ASEA fugals | 14 | 13 | 13 | 12 | 17 | 16 |
| Western States fugals | 9 | 8 | 8 | 7 | 11 | 10 |
| No. paired trials | 3 | | 3 | | 6 | |

customarily boil 0.38 mm grain size, while refineries boil 0.26 mm. The grain size is the average of the dimensions in the b and c axes. Refineries generally have no difficulty in producing C massecuites free of false grain. It is quite clear that, at the lower grain size, refinery massecuites contained a far greater crystal surface area per unit mass of massecuite.

There are many factors to be considered in selecting the appropriate grain size for mill and refinery boil out processes. In mill work at Victoria, the impurity load on the pan station, low grade fugal station capacity, and the fact that most of this capacity is available in batch fugals, suggests that the optimum grain size for C massecuites should be 0.35 to 0.38 mm.

At this stage of the programme a review of the lack of success in consistently boiling clean massecuites in the mechanically-circulated pan suggested these conclusions: the massecuites were being boiled too fast; the evaporation rate exceeded the available deposition rate of sucrose onto the crystals. On one hand the boiling time could simply be extended by controlling steam flow to match that of the naturally-circulated pan. This, of course, would diminish the gains in boiling rate which, after all, was supposed to be the principal benefit of mechanical circulation. On the other hand, the grain size could be reduced to provide more crystal surface area. The disadvantage of this was that it would require longer spin times or more drastic reheating of the massecuite to maintain the purging efficiency.

At this point, the aim was simply to prove that there was a technique for boling massecuites of a quality equivalent to those from the naturally-circulated pan. In a single trial the graining charge from No. 7 pan was run up to 100 tonnes in the No. 6 pan in the usual way and then tightened to dropping weight to see whether false grain formed. This proved successful, and the final grain size was of the order of 0.26 mm. This massecuite was then brought back to boiling weight and split with No. 8 pan since this massecuite could not be dropped because of the limitations of screen size in the batch fugals. With this success, seven trial pairs were boiled, reducing grain size gradually to 0.30-0.32 mm. The results of these trials appear in Table IV.

These data show that exhaustion in the mechanically-circulated pan was inferior to that in the naturally-circulated pan. This was so, even when the boiling time was comparable to or exceeded that in the latter. Even where mechanically-circulated massecuites were deemed to be free of false grain on dropping, their fugalling performance was inferior to the naturally-circulated massecuites. The reason for this was that apparently clean massecuites false-grained in the crystallizer, presumably from the shock on dropping into a vessel, which would have some surfaces significantly cooler than massecuite temperature, thereby producing areas of local high supersaturation.

Four-paired trials were then carried out where the boiling rate in the mechanically-circulated pan was drastically reduced to approach that in the naturally-circulated pan. These results are tabulated in Table V. The results in Trial 3 show that, for comparable boiling rates, the condition of the massecuite dropped was comparable in exhaustion and fugalling quality.

## Conclusions

Generally, it was found that many of the claims made for mechanical circulation were exaggerated. It would appear that maximum crystallization rates as dictated by the inherent crystallizing ability of the molasses can be achieved in well-designed naturally-circulated pans. At higher evaporation rates, the supersaturation is simply increased to the point of promoting false grain formation.

The experience of these trials, and indeed factory experience over five years, showed there were considerable benefits in mechanical circulation under conditions of poor steam supply and refractory boiling material. Despite this, mechanical circulation is unlikely to be installed in future pans.

## Acknowledgements

The authors wish to express their appreciation to CSR Limited for permission to publish this paper.



**TABLE IV—Results of trials showing effect of reducing grain size**

| Trial number | 1 | | 2 | | 3 | | 4 | | 5 | | 6 | | 7 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pan | No. 6 | No. 8 | No. 6 | No. 8 | No. 6 | No. 8 | No. 6 | No. 8 | No. 6 | No. 8 | No. 6 | No. 8 | No. 6 | No. 8 |
| Massecuite true purity | 69.6 | 69.7 | 69.0 | 69.1 | 69.8 | 69.8 | 67.0 | 67.6 | 67.8 | 67.7 | 67.0 | 66.7 | 69.0 | 70.0 |
| Pressure filter molasses true purity | 47.3 | 43.5 | 48.7 | 45.9 | 48.0 | 45.6 | 44.2 | 43.6 | 45.7 | 43.7 | 47.0 | 45.0 | 46.7 | 45.3 |
| Purity drop massecuite to molasses | 22.3 | 26.2 | 20.3 | 23.2 | 21.8 | 24.2 | 22.8 | 24.0 | 22.1 | 24.0 | 20.0 | 21.7 | 22.3 | 24.7 |
| Percent crystal on dropping | 38.6 | 42.6 | 36.1 | 39.2 | 38.2 | 41.4 | 37.3 | 39.1 | 37.0 | 39.0 | 34.3 | 36.0 | 38.0 | 41.3 |
| Massecuite impurity/water ratio on dropping | 3.1 | 3.4 | 3.2 | 3.3 | 3.1 | 3.2 | 3.5 | 3.6 | 3.2 | 3.4 | 3.3 | 3.5 | 3.1 | 3.2 |
| Boiling time—$h_2$ | 3.2 | 3.5 | 2.6* | 4.0 | 3.3 | 3.8 | 4.0 | 6.4 | 3.7 | 3.0 | 2.3 | 3.0 | 5.0 | 5.7 |
| Grain size—mm | 0.40 | 0.42 | 0.39 | 0.41 | 0.37 | 0.39 | 0.33 | 0.38 | 0.34 | 0.36 | 0.35 | 0.34 | 0.32 | 0.30 |
| Presence of false grain—clean, slight, heavy | slight | slight | slight | slight | heavy | clean | slight | slight | slight | clean | clean | clean | clean | clean |
| Fugal spin times—m | | | | | | | | | | | | | | |
| ASEA fugals | 14 | 13 | 15 | 15 | 15 | 15 | 15 | 14 | 15 | 15 | 15 | 15 | 15 | 13 |
| Western States fugals | 9 | 10 | 10 | 10 | 10 | 10 | 10 | 8 | 10 | 10 | 10 | 9 | 8 | 9 |

*Dropped at 75 tonnes instead of usual 85 tonnes.

**TABLE V—Results of paired trials boiled at similar boiling rates**

| Trial number | 1 | | 2 | | 3 | | 4 | |
|---|---|---|---|---|---|---|---|---|
| Pan | No. 6 | No. 8 | No. 6 | No. 8 | No. 6 | No. 8 | No. 6 | No. 8 |
| Massecuite true purity | 69.9 | 69.7 | 67.3 | 67.3 | 67.9 | 67.7 | 68.8 | 68.6 |
| Pressure filter molasses true purity | 47.7 | — | 48.3 | 45.9 | 44.1 | 45.3 | 48.3 | 46.6 |
| Purity drop massecuite to molasses | 22.2 | — | 19.0 | 21.4 | 23.8 | 22.4 | 20.5 | 22.0 |
| Percent crystal on dropping | 38.6 | — | 33.3 | 36.0 | 38.5 | 37.1 | 35.8 | 37.4 |
| Massecuite impurity/water ratio on dropping | 3.0 | 3.3 | 3.2 | 3.3 | 3.0 | 3.2 | 2.9 | 3.1 |
| Boiling time—$h_2$ | 4.2 | 5.3 | 3.9 | 4.3 | 3.4 | 3.3 | 3.4 | 3.7 |
| Grain size | 0.48 | 0.48 | 0.36 | 0.39 | 0.42 | 0.40 | 0.38 | 0.39 |
| Presence of false grain—clean, slight, heavy | slight | slight | slight | slight | clean | clean | slight | slight |
| Fugal spin times—m | | | | | | | | |
| ASEA fugals | 13 | 13 | 12 | 12 | 9 | 9 | 11 | 11 |
| Western States fugals | 10 | 8 | 7 | 8 | 6 | 6 | 7 | 7 |