# ASSESSMENT OF THE GLEDHOW AND TONGAAT FIVES-CAIL BABCOCK CONTINUOUS PANS

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## Abstract

Two Fives-Cail Babcock continuous pans operating on C-massecuite were assessed. The maximum evaporation rates obtained during the tests were 5,3 kg $m^{-2}$ $h^{-1}$ for the Gledhow pan and 6,0 kg $m^{-2}$ $h^{-1}$ for the Tongaat pan. The evaporation rate per unit heating surface was about half that of a conventional batch pan operating on C-massecuite. However, due to the continuous operation and the higher heating surface to volume ratio, the continuous pans have about 20% more capacity than a batch pan of equal volumetric size. The evaporation rates at various conditions, the massecuite residence times in the pans, the effect of steam injection into the massecuite and general observations are presented in this paper.

## Introduction

There were at the time of writing two continuous vacuum pans in operation in the South African sugar industry. Both pans are of the Fives Cail Babcock design but have different types of steam calandrias. The first continuous pan was installed at Tongaat and has been in operation since the 1977/78 season and the other pan was commissioned at Gledhow at the beginning of the 1979/80 season.

The concept of continuous pan boiling affords many advantages over conventional batch systems and he introduction of the two continuous pans has generated much interest locally. There are, however, three aspects in the operation of the pans which are of concern to technologists, namely

1. The relatively low evaporation rates.
2. The very low massecuite circulation without steam injection (jigger).
3. The wide spread in crystal residence time.

In this work an assessment of the two pans has been carried out with emphasis on the three operational parameters mentioned above.

## Description of the pans

The Fives-Cail Babcock (FCB) pan at Tongaat has been described in detail by Graham and Radford.[1] The Gledhow pan is the same design except for the steam calandria which is in one part and is made up of horizontal 30 mm OD tubes instead of vertical plates. The steam is on the inside of the tubes and the massecuite boils on the outside. A brief description of the two FCB pans is given in Table 1.

The feed, to all the compartments of both the pans, was introduced through V-notch weir arrangements and controlled automatically by means of conductivity probes. The steam supply to the pans consisted of vapour one, which at Tongaat was at 145 kPa absolute pressure (dryness fraction: 0,86) and at Gledhow was 170 kPa absolute pressure (dryness fraction: 0,87). The steam pressure in both pans was controlled automatically. Both pans were fitted with facilities for steam (vapour one) injection into the massecuites which, at Tongaat, consisted of 3 cross pieces each having 13 holes of 5 mm diameter in each compartment and at Gledhow 3 T-pieces with three perforations of 9 mm diameter each per compartment.

## Procedure

Evaporation rates were obtained indirectly by measuring the flow of steam condensate from the calandria. At Gledhow, with only one calandria, all the condensate was diverted into a tank fitted with a proportional 20 mm head weir with a pneumatic differential pressure transmitter and bubbler system. This equipment has been described by Moult and Wrathmall.[2]

At Tongaat the condensate flow rate of the front half of the calandria was obtained by measuring the volume in a calibrated tank over a period of time. The condensate from the back half of the calandria was measured with the same weir and bubbler system used at Gledhow.

The quantity of steam injected into the massecuite was measured by recording the pressure drop across an orifice plate fitted in the steam line and determining the steam dryness fraction.[2]

Lithium chloride was used as a tracer to measure the residence time distribution of the crystals in the pan. The lithium chloride solution was injected into the first compartment of the pan through the feed pipe over a period of 15 minutes. The sampling procedure is described in detail by Jullienne and Munsamy.[3] The C-massecuite was sampled at the discharge end of the pan for a period of 3 theoretical mean residence times. The collected C-massecuite samples were analysed for lithium content by atomic absorption spectroscopy as described by Morel du Boil.[4]

Visual observations on the pan operation were made, e.g. microscopic examination of crystals in the feed and massecuite, splashing between compartments, massecuite boiling level and circulation.

## Results

During the period of the tests the Gledhow mill was processing 220 $th^{-1}$ of cane. The pan was designed for 350 $th^{-1}$ of cane and consequently the pan was working below design

**TABLE 1**

**Description of the Gledhow and Tongaat continuous pans**

| Specifications | Tongaat | Gledhow |
|---|---|---|
| (*a*) Design | Fives-Cail Babcock | Fives-Cail Babcock |
| (*b*) Capacity ($m^3$) | 64 | 104 |
| (*c*) Overall dimensions | | |
| Length (m) | 11,9 | 10,4 |
| Diameter (m) | 3,8 | 4,6 |
| (*d*) Steam calandria Arrangement | 2 × 31 Mild Steel Vertical plates | 1 064 S S Horizontal 30 mm OD Tubes |
| Surface area ($m^2$) | 628 | 1 040 |
| (*e*) Number of Compartments | 15 | 14 |
| (*f*) Dimensions of openings between compartments (mm) | 115 × 700 | ± 120 × 950* |

* These dimensions are as originally supplied by the manufacturers. When the tests were performed 7 of the 13 openings had been increased by 50 to 100%.

capacity. The average conditions in the two pans are given in Table 2.

The evaporation rates at different calandria and jigger pressures are given for the two pans in Table 3.

The calculation of the evaporation rate is shown in Appendix 1.

At Tongaat where the measurements of the condensate from the front and back calandrias have been made separately, it was found that the evaporation performance of the front end of the pan with lower brix massecuites was higher by a factor varying between 8 and 42%. The maximum rate measured in the front calandria was 7,0 kg $m^{-2}$ $h^{-1}$, which gave a heat transfer coefficient of 95 $Wm^{-2}$ $°C^{-1}$. It must be noted that the difference would have been much greater if the last three compartments were not being boiled on water.

The actual quantities of jigger steam injected into the massecuites of the two pans are given in Table 4.

The evaporation rate, at different calandria and jigger pressures, of the Tongaat pan is graphically illustrated in Figure 1.

The results of the tracer tests are shown in graphical form in Figure 2. The calculated mean retention times for both pans are shown in Table 5.

The exit age distribution function[5] is plotted against dimensionless time, $\theta$, for both pans in Figure 3. The calculations of E and $\theta$ are shown in Appendix 2.

In spite of the widely spread residence times the crystal size distribution in both the pans was comparable with the average batch pan quality. There was splashing of massecuite between adjoining compartments, but under normal working conditions it was not excessive. In the Gledhow pan the massecuite head over the tube level in the first compartments was important (± 1300 mm above tube level) in spite of the reduced throughput. It was observed that any slight brixing of the massecuite in the front compartments would cause the head to become excessively high. The Tongaat pan, on the contrary, did not present any build up in head, in spite of the fact that this pan was producing 50% more massecuite than the Gledhow pan. On inspecting this pan at the end of the season it was found that some of the wall dividers had fallen off, which could possibly explain the relatively easy passage of the massecuite. The pans were found to boil more violently in the front, lower brix compartments than in the back, higher brix compartments. The average brix profiles for the two pans are shown in Figure 4.

The effect of jigger steam on pan circulation was found to be of prime importance. The circulation of massecuite was almost non-existent without steam injection especially in the higher brix compartments.

Both pans were inspected at the end of the season and no scale was present in the Gledhow pan, but a soft, thick (± 1 mm) scale was found in the Tongaat pan, which was more prominent at the back end of the pan.

## Discussion

The evaporation performance of the Gledhow and Tongaat continuous pans was assessed over a range of pressures varying from 5 kPa gauge to 40 kPa gauge for the calandria and + 10

TABLE 2
Average conditions in the two FCB continuous pans

| Parameters | Tongaat | Gledhow |
|---|---|---|
| Crushing rate ($th^{-1}$) | 340 | 220 |
| Massecuite production ($th^{-1}$) | 18,6 | 13,0 |
| Seed volume % massecuite volume | 27 | 30–40 |
| Seed — Brix | 90,4° | 90,2° |
| Purity | 61,7 | 58,0 |
| Crystal size (mm) | — | 0,05 × 0,10 |
| Massecuite — Brix | 95,4° | 96,8° |
| Purity | 56,0 | 53,3 |
| Crystal size (mm) | — | 0,09 × 0,16 |
| B-Molasses — Brix | 75° | 68° |
| Purity | 50 | 50 |
| Calandria pressure (kPa) | 40 | 5–50 |
| Injection steam pressure (kPa) | 0 | – 50 |
| Pan vacuum (kPa) | – 92 | – 92 |
| Boiling temperature (°C) | 60 | 60 |

TABLE 3
Evaporation rates of the two FCB pans at varying calandria and jigger pressures

| Pan | Calandria Pressure (kPa gauge) | Jigger Pressure (kPa gauge) | Condensate Flow Rate ($th^{-1}$) | Evaporation Rate (kg $m^{-2}$ $h^{-1}$) | Calculated Heat Transfer Coefficient ($Wm^{-2}$ °C-1) |
|---|---|---|---|---|---|
| Gledhow | 47 | – 20 | 5,9 | 5,3 | 69 |
| Gledhow | 47 | – 50 | 5,0 | 4,5 | 59 |
| Gledhow | 11 | – 25 | 5,0 | 4,5 | 70 |
| Gledhow | 11 | – 50 | 3,8 | 3,4 | 53 |
| Gledhow | 11 | closed | 0,5 | 0,4 | 6* |
| Tongaat | 38 | 0 | 4,1 | 6,0 | 82 |
| Tongaat | 38 | + 10 | 4,0 | 5,9 | 80 |
| Tongaat | 38 | – 25 | 3,6 | 5,3 | 72 |
| Tongaat | 38 | – 50 | 3,0 | 4,4 | 60 |
| Tongaat | 40 | 0 | 3,9 | 5,6 | 73 |
| Tongaat | 40 | closed | 2,7 | 4,0 | 54 |
| Tongaat | 20 | 0 | 3,3 | 4,8 | 71 |
| Tongaat | 20 | + 10 | 3,4 | 5,0 | 74 |
| Tongaat | 20 | – 25 | 3,0 | 4,4 | 65 |
| Tongaat | 20 | closed | 2,2 | 3,2 | 47 |
| Tongaat | 10 | + 10 | 3,0 | 4,4 | 69 |
| Tongaat | 10 | 0 | 3,0 | 4,4 | 69 |
| Tongaat | 10 | – 25 | 2,7 | 4,0 | 63 |
| Tongaat | 10 | closed | 2,0 | 2,9 | 46 |

* The test period in this run was shorter than the others.

TABLE 4
Quantity of jigger steam used in the two FCB pans

| Pan | Jigger Pressure (kPa gauge) | Pan Vacuum (kPa gauge) | Quantity of Steam injected ($th^{-1}$) |
|---|---|---|---|
| Gledhow | − 50 | − 92 | 0,35 |
| Gledhow | − 22 | − 92 | 1,11 |
| Gledhow | − 20 | − 92 | 1,10 |
| Tongaat | − 50 | − 92 | 0,28 |
| Tongaat | − 25 | − 92 | 1,25 |
| Tongaat | 0 | − 92 | 2,08 |
| Tongaat | + 10 | − 92 | 1,86 |

TABLE 5
Residence time of massecuites in the two FCB pans

| Pan | Tracer peak (hours) | Mean residence time (hours) |
|---|---|---|
| Gledhow .. .. .. .. | 16,0 | 16,7 |
| Tongaat .. .. .. .. .. | 8,0 | 9,5 |

kPa to none at all for the jigger steam. Within the range tested increases in calandria and/or jigger pressures were found to improve both the evaporation rate and the heat transfer coefficient of the pans although the Tongaat results are an indication that not much improvement in evaporation performance can be achieved by increasing the jigger pressure above 0 kPa. The highest evaporation rate was 6,0 kg $m^{-2}$ $h^{-1}$ at a calandria pressure of 38 kPa and a jigger pressure of 0 kPa for the Tongaat pan and 5,3 kg $m^{-2}$ $h^{-1}$ for the Gledhow

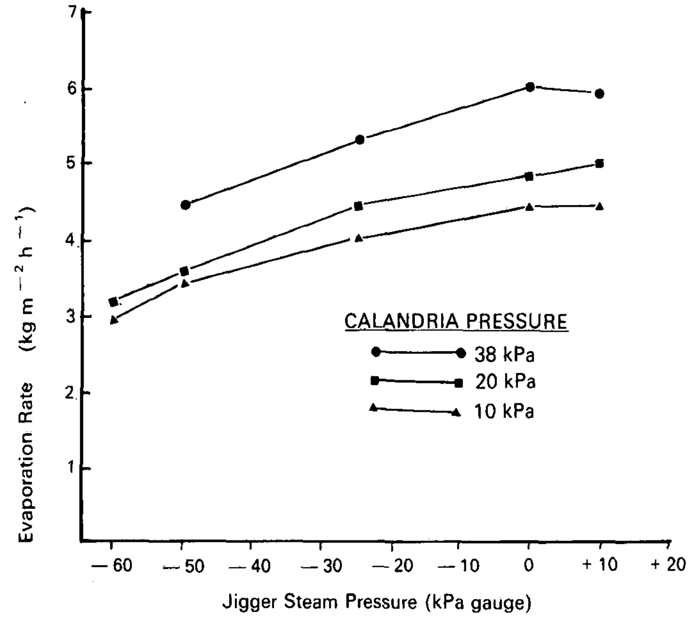

**FIGURE 1** Evaporation rates of the Tongaat FCB pan at different calandria and jigger pressure.

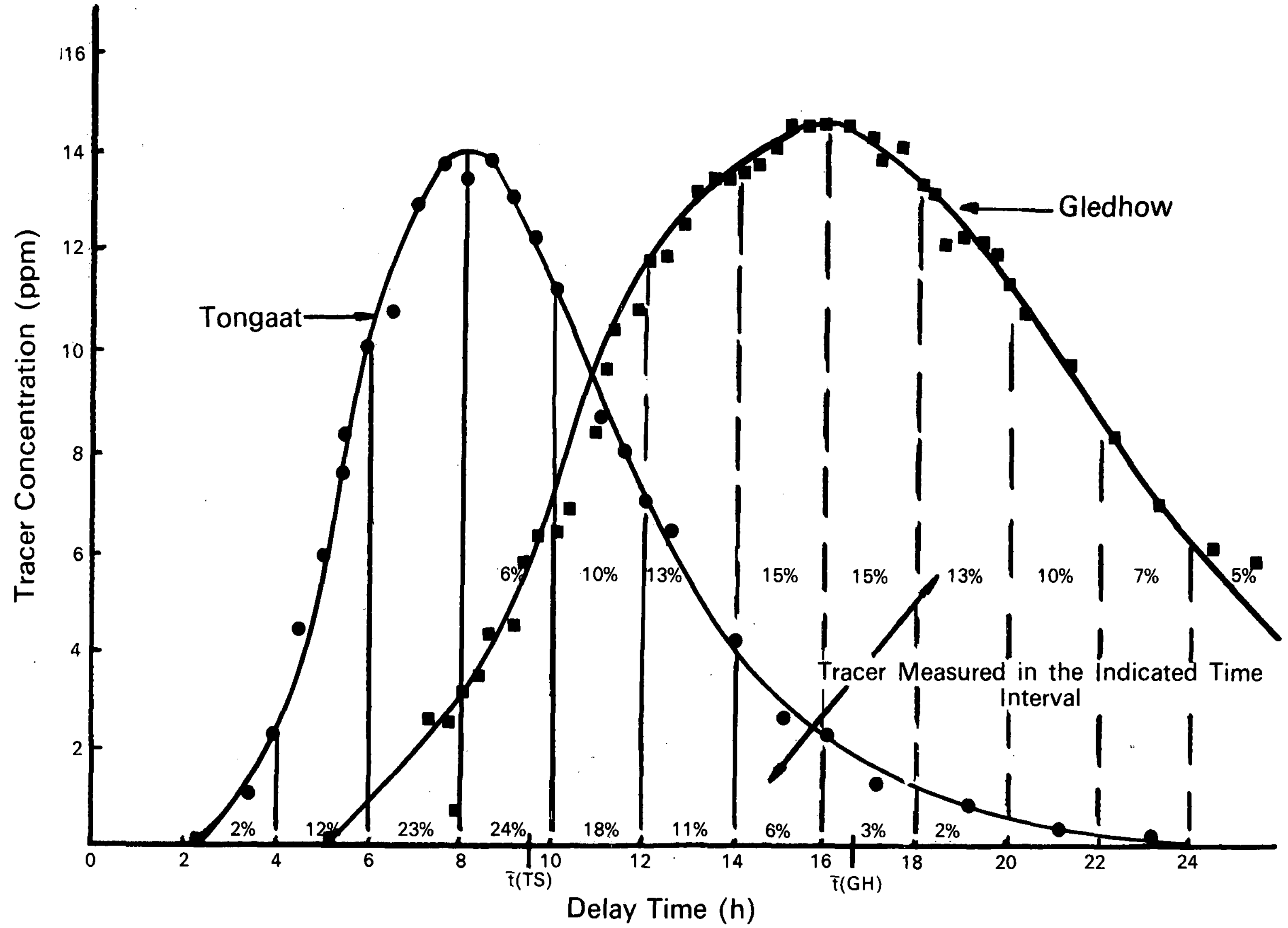

**FIGURE 2** The residence times of the massecuites in the Gledhow and Tongaat FCB pans.

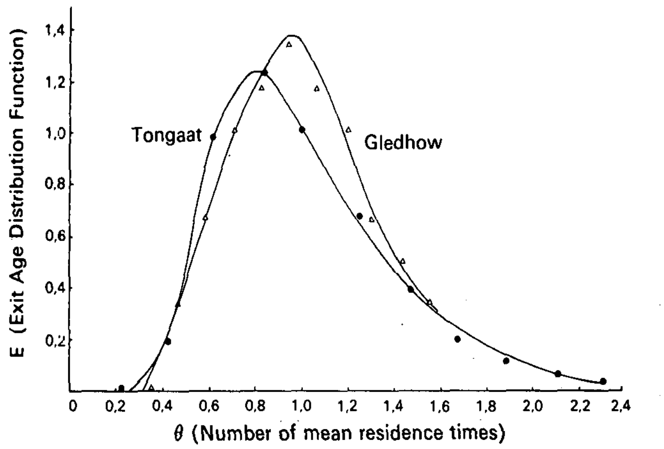

**FIGURE 3** The exit age distribution function of the massecuites in the two FCB pans.

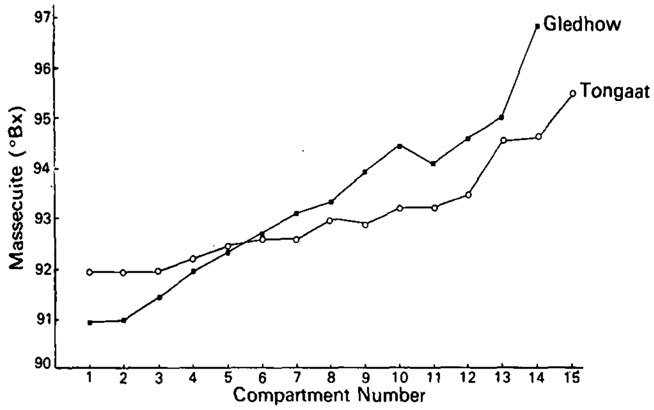

**FIGURE 4** Brix profiles of the Tongaat and Gledhow FCB pans.

pan at a calandria pressure of 47 kPa and a jigger pressure of — 20 kPa. The corresponding heat transfer coefficients are 82 $Wm^{-2}$ $°C^{-1}$ for the Tongaat pan and 69 $Wm^{-2}$ $°C^{-1}$ for the Gledhow pan. The jigger pressure at Gledhow was not increased beyond — 20 kPa because of the risk of excessive splashing due to the high level of massecuite in the front compartments. However, a comparative analysis of the full set of results shows that both pans would have almost identical evaporation rates and heat transfer coefficients under similar calandria and jigger conditions.

Based on the more complete Tongaat results it was found that at equal jigger pressure a drop in calandria pressure from 38 to 10 kPa gauge would cause a ± 25% reduction in evaporation rate. On the other hand, at equal calandria pressures a change in jigger pressure of 25 kPa gauge would result in a ± 10% change in evaporation rate. For a 50 kPa gauge jigger change the evaporation rate changed by ± 25%.

Generally, it would appear that the evaporation rate (per unit heating surface) of the FCB continuous pans boiling C-massecuites would be about 50% that of a conventional tubular calandria batch pan. The continuous pans, however, have a heating surface to volume ratio which is double that of a batch pan and, consequently, at equal volumetric capacity the two types of pans will have the same evaporation capacity. However, since the down time of a batch C-pan in an average installation is about 20%, and the continuous pan has none, the latter will have a 20% higher production rate. An improvement in the heat transfer would possibly not increase the pan capacity which is limited by the rate of crystallisation but would have the advantage of reducing the heating surface and/or the steam pressures.

The quantity of jigger steam in the pans was nearly 2 $th^{-1}$ at the optimum pressure of 0 kPa gauge. (This is equivalent to 11% on massecuite at Tongaat and 15% at Gledhow) which is approximately 50% of the vapour produced by heat transfer in the Tongaat pan under normal operating conditions.

The residence times of massecuite in the Tongaat and Gledhow pans were, as could be expected, widely different because of the higher throughput of massecuite in the smaller Tongaat pan. The two residence time distributions were, however, found to possess the same basic characteristics as evidenced by the almost identical curves of Figure 3. The shape of the Tongaat pan curve tends to indicate a certain amount of by passing which may well be the case due to the collapse of some of the wall dividers between compartments.

## Conclusions

The two FCB continuous pans at Gledhow and Tongaat were found to have evaporation rates equivalent to about half that of a batch C-pan in spite of which it is estimated that they possess about 20% higher production rate because of their higher heating surface to volume ratio and the non-stop operation. The use of steam injection into the pan was found necessary to obtain optimum heat transfer rates and massecuite circulation. In spite of the widely spread massecuite residence times in the pans the crystal size distribution was found to be comparable with batch pan quality.

The size of the opening between compartments at Gledhow was inadequate and could not cope with the lower than designed massecuite throughput.

The ease of operation and control, associated with the many advantages resulting from the steady process steam and condenser water requirements, together with the continuous production of massecuite make the FCB continuous pan a most attractive proposition.

## Acknowledgements

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## APPENDIX 1

$$\text{Evaporation Rate} = \frac{\text{Condensate flow rate}}{\text{Heating Surface}} \times \frac{\text{Enthalpy vapour one}}{\text{Enthalpy pan vapour}}$$

## APPENDIX 2

$$E = \frac{C}{\Sigma C\ \Delta t} \times \bar{t}$$

$$\theta = \frac{t}{\bar{t}}$$

E = Exit age distribution function
C = Concentration of trace at time, t
$\Delta t$ = Time interval between sampling, $t^1$-t
t = Time after tracer injection
$\bar{t}$ = Calculated mean residence time
θ = Dimensionless time.