PRELIMINARY EVALUATION OF MODIFICATIONS TO THE CCTR, FCB CONTINUOUS PANS AT ESTON AND SEZELA

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Abstract

Five, Fives Cail Babcock (FCB) continuous vacuum pans have been installed in South Africa. A first pan of 64 m^3, with plate calandria type, for C-massecuite was installed in 1976 in the Maidstone mill of the Tongaat-Hulett group. In the Illovo Group, a first CCTR pan of 104 m^3 for C-massecuite was installed in 1980 in the Gledhow mill, and in 1981 two CCTR pans of 90 m^3 each for B- and C-massecuite were installed in the Illovo mill (mill transferred to Eston in 1995) and one CCTR pan of 90 m^3 for C-massecuite in the Sezela mill. These pans were originally designed for the beet sugar industry, where viscosities are much lower than in the cane sugar industry. The initial performance of the pans, in terms of throughput and exhaustion, was poor on low grade massecuites due to poor circulation.

In 1995, the Eston pan was installed in series with a Tongaat Hulett Sugar (THS) vertical tube type continuous pan and the performance was evaluated. It was found that the capacity of the THS type pan with an equivalent heating surface was twice that of the FCB pan. Modifications were carried out on the FCB pan to double its capacity and improved its performance. The Sezela pan was modified in a similar manner and then evaluated against the Sugar Research Institute (SRI) continuous pan, on lower grade massecuites. This paper discusses the modifications and improved results achieved at both the Eston and Sezela mills.

Introduction

The FCB pan was first introduced in the South African industry in 1977 at Maidstone. This pan was fitted with vertical plate heating elements. Because of the high viscosities in the South African sugar industry, a number of modifications had to be made to this pan, e.g jigger steam facilities. This resulted in improved throughputs at calandria pressures of about 50 kPa gauge (Rein, 1986). Similar results were observed with the FCB pans later installed at Sezela and Eston.

The old Illovo mill had two FCB pans of 90 m^3 capacity, which were originally used for boiling B- and C-massecuites. Due to poor performance on the low grade C-massecuites, it was decided to change the duty to a higher grade massecuite. At Sezela, a 90 m^3 FCB pan was installed in 1981 to boil C-massecuite and a 90 m^3 SRI pan was subsequently installed in 1984 for additional C-massecuite capacity. In 1986 the FCB 'C' pan performance was evaluated against the SRI pan, and the findings of Munsamy (1988) indicated that the FCB pan showed poorer exhaustion and poorer natural circulation than the SRI pan. As a result, this pan was set aside in 1988 and was used only for short durations in 1992 and 1997, when additional pan capacity was required. A need for pan capacity in the group provided an opportunity to re-evaluate the FCB pan performance. The pan was re-assessed during October and November of the 1998 season after completion of modifications similar to those done earlier at Eston mill. The improved results in massecuite circulation, pan capacity and performance are described in this paper.

Design specifications of the CCTR FCB pan at Eston and Sezela

The calandria of the FCB CCTR (Cuite Continue with Tubes with Round body) type continuous vacuum pan consists of horizontal tubes arranged in vertical layers 50 mm apart and 18 mm between the tubes, through which the steam flows and condenses. The pan calandria consists of two steam passes designed to ensure methodical sweeping of condensate in the tube. A reported advantage of this sweeping is that it maintains a sufficient steam speed through the tubes which permits the condensates and non-condensible gases to be removed correctly (Journet, 1998). This process needs to be fully understood and taken into account when making changes to the steam supply or condensate removal system.

A brief description of the two FCB pans is given in Table 1.

Table 1. Description of Sezela and Eston pans.

Specifications	Before modifications	After modifications	
		Sezela	Eston
(a) Capacity	90 m^3	-	-
(b) Overall dimensions length	9 65 m	-	-
diameter	4 6 m	-	-
(c) Tube arrangement	Horizontal	-	-
(d) Tube diameter	30 mm	-	-
(e) Number of tubes	1 064	1 022	998
(f) Calandria heating surface	892 m^2	856 m^2	836 m^2
(g) Number of compartments	12	12	12
(h) Tube bundle arrangement	Two pass	-	-
(i) Heating surface volume ratio	9 91	9 51	9 28
(j) Dimension of openings between	120x950 (ES)	300x1300	210x950 (8 cells)
compartments (mm) on centre	210x950 (SZ)	-	250x950 (4 cells)
(k) Tube length	8 9 m	-	-
(l) Jigger steam tubes	Nil	8	10
(m) Reduction in heating surface		4 0%	6 4%

Both steam passes are equipped with condensate extraction facilities and incondensible gas is extracted at the end of the second pass. The latter may be vented either to atmosphere or into the condenser, thus allowing the pan to be boiled with calandria steam at sub-atmospheric pressures. On both Eston pans there is a second incondensible gas point at the end of the first pass, which was eliminated as it was felt that it would interfere with the steam velocity and hence the sweeping of condensate in the tubes. The pans at Eston mill are also equipped with the following:

- Absolute pressure control
- Calandria and jigger steam pressure control
- Controllable seed rate
- Syrup flow rate indication
- Supersaturation control by conductivity and radio frequency probes
- Sezela pans were originally provided with similar controls.

Experiences prior to modifications

Illovo mill 1988-92

Due to poor circulation, in 1988 the FCB C-continuous pan at the Illovo mill was modified to boil A-massecuites in a semi-continuous mode, i.e. in series with a 30 m^3 receiver and three batch pans, which were used for brixing up, as the FCB pan did not have the capacity to handle all the A-massecuite.

Seed for the continuous pan was supplied by B-magma from two large casing, Western States continuous centrifugals, pumped directly into the FCB pan. When these machines stopped no feed was available, causing the pan to slow down or shut down completely.

Poor performance during the 1988 season showed that further development work and modifications were required if it was to be successful. The following problems were encountered:

- The working cycle was relatively short. Evaporation rates dropped off dramatically after a few days and the pan had to be boiled out. Severe encrustation on the unheated surfaces resulted in lumps, which broke off and blocked the tube nest.
- A consistantly wider crystal size distribution was experienced together with a deterioration of the other quality parameters, namely colour, pol and fines.
- Encrustation on the baffles and pan walls was so serious that evaporation rates dropped after a few days causing a build-up of syrup stocks and blocked exit piping. This necessitated weekly boil-outs with water.

It was also observed that the FCB pan worked well at a lower brix profile. This could be due to poor circulation because of the excessive depth of the calandria and high hydrostatic head on the bottom of the calandria. The space between the pan shell and bottom tubes was only 125 mm, resulting in flow restriction when high brix massecuites were boiled.

Sezela mill 1982-92

The FCB pan performance was poor since its commissioning on C-massecuite boiling in 1981. The installation of a second continuous pan of the SRI design showed a remarkably improved C-exhaustion. Due to lower exhaustion of the FCB pan, despite a higher evaporation rate, both the SRI and FCB pans were tested in 1986 under controlled conditions, where the calandria and jigger steam pressures, pan vacuum, pan temperature and seed rate were kept the same.

The results indicated that the FCB pan nutsch was always higher, and the average difference was 2,2 units in favour of the SRI pan. The FCB pan achieved an evaporation rate of 5,5 kg/m^{2}h compared with the 3,9 kg/m^{2}h of the SRI pan.

The increase in jigger steam pressure in the FCB pan from 0 to 5 kPa g increased the evaporation rate by 57% from 3,73 to 5,87 kg/m^{2}h, while an increase in jigger steam on the SRI pan from 0 to 50 kPa increased the evaporation rate by 37% from 3,88 to 4,62 kg/m^{2}h.

The increase in calandria pressure in the FCB pan from 5 to 30 kPa g increased the evaporation rate by 45% from 3,56 to 5,16 kg/m^{2}h. A similar increase in calandria pressure in the SRI pan increased the evaporation rate by only 16% from 3,91 to 4,53 kg/m^{2}h.

The above results showed that the increase in calandria and jigger pressures had more impact on the FCB than the SRI pan; this implied that the SRI pan had a better natural circulation than the FCB pan.

In 1992, the FCB pan was modified to six compartments to allow for an unrestricted passage of massecuite between the compartments. The pan was evaluated on B-massecuite boiling. The results indicated that, while the design evaporation rates were achieved, exhaustions remained low. With this in mind, modifications were carried out to improve the natural circulation characteristics by removing a bank of tubes at the lower end of the pan and further enhance the jigger steam arrangement.

Modifications and design changes

ESTON MILL

Design layout

With the move of the old Illovo mill to Eston in 1995-96 it was decided to go fully continuous on A-massecuite boiling. This meant scrapping three batch pans and replacing them with a 90 m^3 vertical tube type continuous THS pan with approximately the same volume and heating surface as the existing FCB pan, the remaining FCB pan being retained on B duties. Figure 1 shows the new boiling cycle with the two continuous pans in series.

Modifications

During the 1997 and 1998 off-crops various modifications were made to the two FCB pans in an attempt to improve their performance. These included:

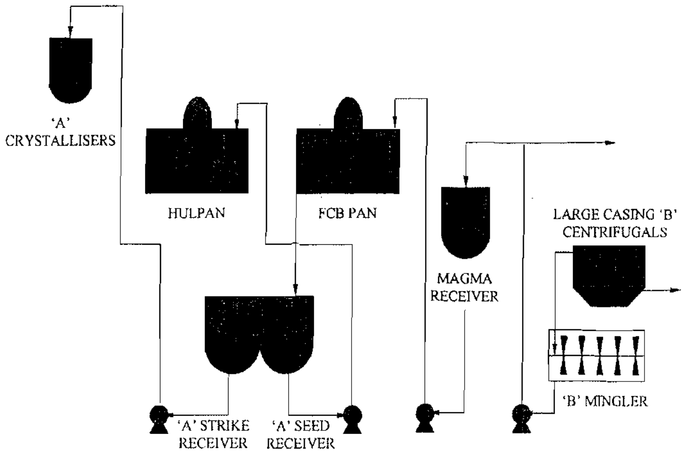

Figure 1. A-pan station layout at Eston mill.

Calandria modifications

- Fifty-six tubes were removed from bottom section of the tube bundle to increase the space between tube bank and vessel, to improve calandria refeeding with massecuite and thus improve circulation (Figure 2).

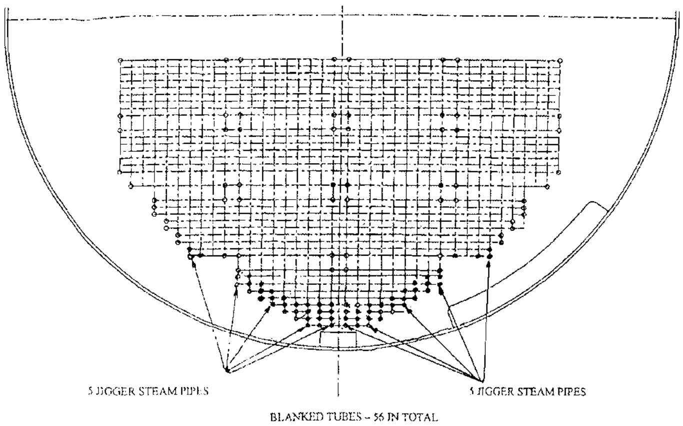

Figure 2. Calandria modifications.

Jigger steam modifications

The jigger steam had always been a cause for concern with the FCB pan. On inspection of the pan the original jigger steam manifold in the pans was found to be seriously corroded (i.e. holes >15 mm instead of 6 mm) and had to be renewed.

The inaccessibility of the jigger manifolds made this impossible to renew unless one third of the tubes were removed or the pan shell was cut. It was also observed that the jigger piping was choking and had to be cleaned continuously, affecting throughput and performance. As a result of these problems, 10 tubes at the lower end of the pan were subsequently converted to jigger steam as shown in Figure 2.

All jigger steam piping was connected to a 50 mm steam manifold at both ends of the calandria, with its own non-return valve and manually operated regulating valve so that the flow could be regulated to the front or the rear end of the pan. Each converted jigger steam pipe has 50 holes of 6 mm diameter facing downwards, except for the two centre jigger steam pipes, which have been directed towards the bottom passages (Figure 3) so as to keep the passages clean and promote circulation in the centre of the pan. All jigger steam is automatically controlled on a pressure of 75 kPa absolute. A further eight steam tubes surrounding the jigger pipes have been removed to make more efficient use of the jigger steam and improve the pan circulation.

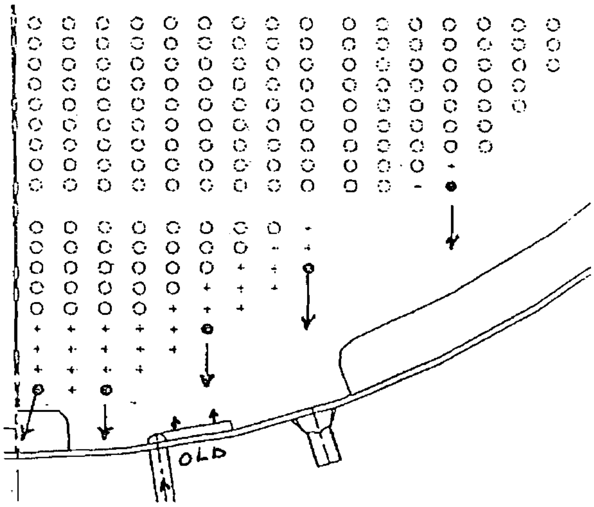

Figure 3. Position of jigger steam piping and direction of jigger steam flow.

Encrustation

Prior to 1989, severe encrustation on the sides and baffles of the FCB A-pan seriously affected pan performance. The FCB pans had no facility to avoid or reduce encrustations above the massecuite level. The pan had to be boiled out on a weekly basis. In order to increase the running time between boil-outs, the following process was used once per shift: steam injection in vapour space (used steam pressure ≈ 1,5 bars abs) up to an approximate temperature of 90°C. During the process, which took about 10 minutes, steam to calandria and cold water to condenser were closed, but conductivity control of the massecuite (liquor feeding) continued to run. This process was permitted to run for four weeks before boiling out, without special noticeable effect on crystallisation.

Encrustation on the FCB B-continuous pan was less severe when the pan was not steamed out; however, without steaming the pan, severe lumps appeared after five weeks of operation, resulting in serious curing problems and reduced throughput. A similar steaming out procedure was therefore successfully carried out on this pan.

Massecuite passages

Massecuite passages under the longitudinal partition conform to the description in Figure 4. The width of these apertures (total width) is in the order of 950 mm and the height is in the order of 120 and 210 mm.

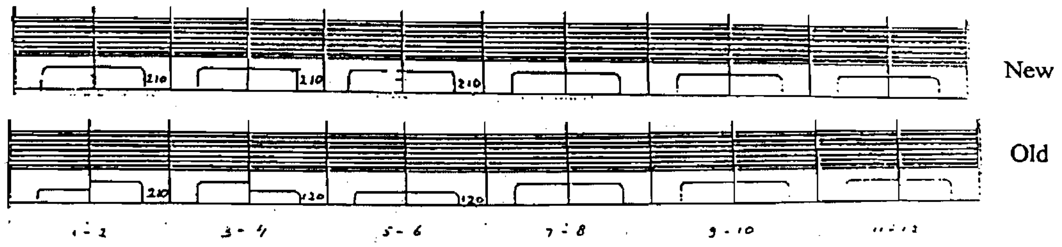

Figure 4. Massecuite passages under longitudinal partition before and after modification.

Sezela mill

Similar modifications were completed in October 1998. These were:

- Conversion from six cells to the original twelve cells.
- Removal of 42 tubes from the bottom section of the pan. This reduced the heating surface by 4% (as shown in Table 2).
- Fitting of eight 30 mm diameter, 9 m long jigger steam pipes with 4 mm holes distributed 150 mm apart.

Assessment procedure

At Eston, the FCB A-pan was monitored once per two week cycle and the relevant data recorded. Evaporation rates were obtained by measuring the flow of condensate from the calandria. There was no facility for measuring the quantity of jigger steam injected, so the jigger steam pressure was kept constant or shut off completely when necessary.

The quantity of massecuite produced was obtained by measuring the level in the seed receiver over a period of time. The quantity of magma used was obtained by physically calibrating the variable speed seed pump with containers of known volumes. The evaporation rate was measured under various conditions, i.e. calandria and vapour space pressures, jigger steam pressures, feed density, massecuite boiling levels, massecuite temperatures and overall pan brixes.

Samples were taken of the products entering and leaving the pan. Visual observations were made of encrustations, splashing, circulation, gradient across the pan and microscopic examination of all products.

At Sezela, the FCB pan conductivity was measured on alternate cells and seed rate was controlled by varying the speed of the seed pumps. Nutsch samples were taken once per shift and compared with the batch pan in the case of the B-massecuite and the SRI pan in the case of the C-massecuite.

All operating parameters relating to calandria pressures, massecuite temperatures, massecuite brixes and feed brixes were kept constant. These are given in Table 2. Visual observations were made on the pan operations, e.g. microscopic examination of crystals in the feed and massecuite, splashing between compartments and massecuite circulation. While no evaporation was measured on the FCB pan, the massecuite throughput and feed stock levels were monitored and this indicated that the pan was performing to capacity.

The pan was assessed on B-massecuite boiling for three weeks, and C-massecuite boiling for two weeks. The pan was boiled manually with minimum instrumentation during this test period.

Table 2. Pan operating conditions during 1998 season at Sezela.

Parameter	SRI	FCB
Calandria pressure (kPa g)	45	45
Jigger steam pressure (kPa g)	-15	-15
Massecuite temperature (°C)	68	68
Massecuite brix	97	96 5
Evaporation rate (kg/m^2/hr)*	3 9	5 5

*Measured 1987 season and compared favourably with current calculated data

Results and Discussion

Eston mill

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 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 (Rein, 1986).

The evaporation rate for the A-pan was initially found to be 9,3 kg/m^{2}h and increased to 17,79 kg/m^{2}h after the modifications (Table 3).

Removing the 56 bottom tubes and converting 10 tubes to jigger steam has resulted in an increase in pan throughput from 23 to 45 m^3 syrup per hour at 65° brix.

The increased throughput and improved performance are shown in Table 3.

No effort was made to exhaust the A-seed, but it is highly significant that A-massecuite exhaustion increased by four units for the 1998-99 season after the FCB A-pan modification.

At Eston mill, the steaming out procedure reduced encrustation in the FCB pan with no detrimental effect on crystallisation and this contributed to boiling the pan for four weeks without a boil-out. This resulted in a saving in downtime, increased throughput and improved massecuite quality, free of lumps.

Table 3. FCB A-pan performance before and after modifications at Eston mill.

	Parameters	Before modifications	After modifications
Cane crushed per hour	Tons	201	260
Syrup pump rate	m^3/h	18 17	39 36
Syrup	Brix %	62 40	63 66
	Purity	86 83	87 37
B-magma pump rate	m^3/h	3 74	6 08
B-magma	Brix	90 10	91 38
	Purity	90 68	91 63
	Average crystal size (microns)	360	340
	Crystal content %	52	48
Magma vol % exit seed vol		20 60	19 69
A-seed production rate	m^3/h	14 84	30 88
A-seed	Brix %	90 52	90 02
	Purity	88 22	87 32
	Average crystal size (microns)	510	530
	Crystal content %	43	44
Calandria pressure (V1)	kPa g	40 00	19 24
Pan vacuum	kPa g	80 00	70 63
Pan boiling temperature	°C	75 00	69 74
Evaporation rate	kg/m^2h	9 30	17 79
Heat transfer coefficient	$kW/m^{2}°C$	0 143	0 370

During the 1997 off-crop modifications were carried out on the large casing B-magma centrifugal. Higher capacity WS 30 x 37 centrifugals replaced the WS 34 x 34 centrifugals. Consequently the speed was reduced from 2 100 to 1 800 rpm. This resulted in a lower CV (coefficient of variation) of B-magma.

Sezela mill

While the pan nutsches given in Table 4 did not compare favourably with the batch pan, the vigorous circulation in the pan indicated a vast improvement in evaporation rate compared with previous boilings, and better than those reported by Munsamy (1988). Visually there was a significant increase in crystal size distribution across the cells. The performance results were affected by mechanical problems, and the absence of computerised pan control resulted in a lack of constant feed and poor brix control. The efficiency of the jigger steam device of the FCB pan is better than that of the SRI pan and the heat transfer coefficients of the FCB pan is better than those of the SRI pan because of the higher evaporation rate which equivalent totals delta-t.

Table 4. performance comparisons on B- and C-massecuite boiling at Sezela.

	B-massecuite			C-massecuite		
	FCB	Batch	Diff	FCB	SRI	Diff
Mass Brix	94 5	94 7	-0 2	96 2	96 2	0
Mass Purity	68 1	69 0	-0 9	54 8	55 9	-0 9
Pan Nutsch	49 3	46 9	2 4	44 4	42 3	21

The current plan is to automate the FCB pan and commission it in series to the existing SRI pan, as shown in Figure 5. The additional boiling capacity is expected to result in larger C-crystal size and will give the flexibility to achieve the desired C-massecuite purity. Theoretically, this larger crystal size and higher brix is estimated to be worth an improvement in target purity difference of final molasses (TPD) of approximately 1,2 units.

At Sezela mill, encrustation was evident during the five week trial period, particularly during B boiling. Some severe scaling of the vertical tubes in the SRI pan had been observed during the off-crop. The FCB pan appears less susceptible to encrustation, as the massecuite is able to go around the tubes, laterally or longitudinally, and this tends to diminish the scale by attrition.

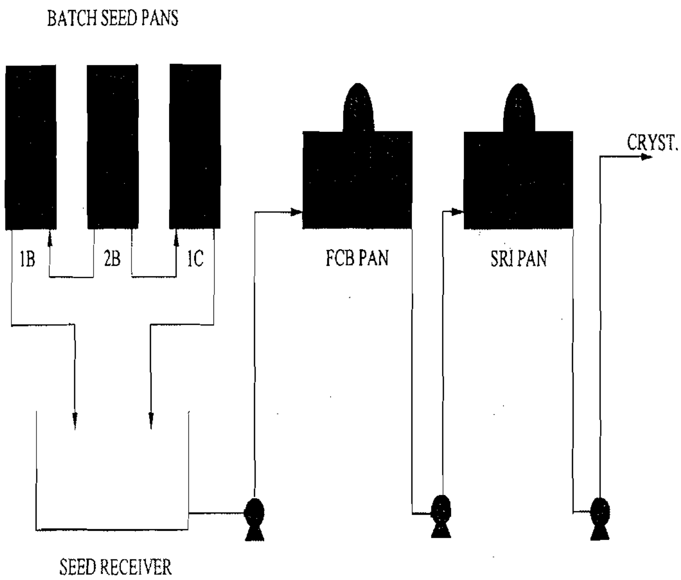

Figure 5. C-pan station layout at Sezela mill.

Conclusion

These trials proved that the modifications have resulted in improved circulation and pan performance without affecting the evaporation rate, despite a reduction of approximately 5% in heating surface.

The installation of the additional jigger steam pipes aided circulation in the higher brix compartments. These pipes are easily accessible and less susceptible to blockages and wear, than the original jigger manifolds. The opening of the passages has also improved circulation and throughput.

At Sezela, given the right control instruments and with consistent feed, the FCB pan should achieve an improved crystal size and hence higher exhaustion. The recommissioning of this pan, after the modifications, will lend support to the automated pan floor at Sezela, resulting in improved thermal efficiency and better plant utilisation.

In summary, benefits due to modifications carried out on the Eston and Sezela pans are:

- improved circulation
- improved throughput and process continuity
- improved A-massecuite exhaustion

- improved crystal formation
- improved plant utilisation
- less encrustation due to steaming out procedure
- more efficient steam agitation (jigger steam).

As a result of the successful modifications to the FCB A-pan, the FCB B-pan at Eston has been modified during the 1998 off-crop. The expected improved pan performance should produce a better quality B-magma and consequently a better A-seed. This should further improve the coefficient of variation (CV) of the A-massecuite, as the CV of the A-seed will determine the CV of A-massecuite. A planned further reduction of the speed of the large casing B-magma centrifugals from 1 800 to 1 600 rpm should result in less crystal breakage and hence an improvement in CV. This is expected to bring the FCB pan in line with batch pans and other type continuous pans.

Acknowledgements

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