EVALUATION OF THE STG HIGH GRADE CONTINUOUS CENTRIFUGAL AT HULETTS REFINERY

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Abstract

Due to the benefits reported on the use of continuous centrifugals in refineries elsewhere in the world, it was decided by Tongaat-Hulett Sugar Ltd to evaluate the Schultz, Tait and Greig (STG) continuous centrifugal at their sugar refinery in Durban, South Africa. This paper deals with the installation, commissioning and evaluation of the continuous centrifugal. Results of tests done on first and second refined massecuites are presented. Some problems experienced during the trial are discussed, and the benefits of using continuous centrifugals in the refinery are given.

Keywords: STG continuous centrifugal, high grade continuous, refinery continuous centrifugal

Introduction

The continuous centrifuging of high grade massecuites offers a number of advantages, with the main benefits being higher throughputs and lower power consumption. Some of the earlier problems experienced with the development of continuous centrifugals for high grade massecuites were related to the quality of the sugar crystal, in terms of crystal breakage and the formation of lumps in the sugar. The first successful high grade continuous centrifugal was developed and evaluated in Australia (Greig *et al.,* 1994). In the development of this continuous centrifugal (Greig and Bellotti, 1996) the objectives were to control the trajectory of the crystals after leaving the basket so as to decelerate them without incurring crystal breakage, and the creation of a self-cleaning impact surface to prevent the formation of lumps in the sugar. These goals were achieved with the use of a 25° basket angle, lower basket speeds (compared with batch centrifugals), a static crystal deflector and a system to prevent the formation of lumps.

A number of workers have evaluated continuous centrifugals in raw sugar factories (Wong Sak Hoi and de Rosnay, 1996; Zondo *et al.*, 1998) and in refineries (Greig *et al.,* 1994). The results from an Australian refinery (Greig *et al.,* 1994) showed that the Schultz, Tait and Greig (STG) continuous centrifugal produced refined sugar equivalent in terms of colour and crystal quality to that of batch centrifugals.

The Huletts refinery has a programme in place to replace existing ageing BMA V1250 batch machines. Due to the many benefits associated with continuous centrifugals it was therefore recommended by Schorn (2001) that the refinery consider evaluating an STG centrifugal as a replacement for some of the existing batch machines.

The STG centrifugal has a stainless steel 25° angle basket with a maximum internal diameter of 1100 mm. The basket jet chamber and deflector ring are constructed of stainless steel, and the casing bearing housing and discharge hopper are constructed of carbon steel.

The centrifugal is equipped with an internal crystal deflector system, which prevents damage to the refined sugar crystal. An independently driven blending or disperser device housed in the lower section of the discharge hopper prevents the formation of lumps in the discharging refined sugar. The operation of the centrifugal is automatically controlled by a PLC control system. Special features of the centrifugal include vibration and bearing temperature monitoring systems. The centrifugal has an automatically controlled water wash and crystal lubrication system to ensure optimum refined sugar quality. The centrifugal is driven by a flange-mounted six-pole electric motor, which is fitted onto a steel support platform directly above the basket. The nominal installed power of the centrifugal motor is 45 kW. The centrifugal uses 1,52 m^2 open area chromium plated nickel screens with 150 micron slots. A schematic drawing of the STG centrifugal is given in Figure 1 and a photograph of the centrifugal installed at the refinery is given in Figure 2.

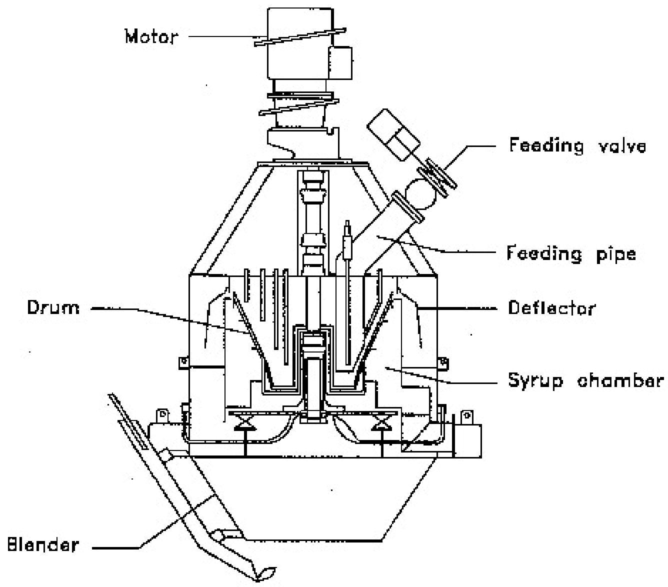

Figure 1. The STG 110 HW continuous refinery centrifugal.

Figure 2. The STG continuous centrifugal installed at the Huletts refinery in Durban.

Experimental

The STG 110 HW continuous centrifugal was installed by the middle of November 2002 in a bay which also housed four batch BMA V 1250 centrifugals. All sugar that was cured by the batch and the continuous centrifugals was dried by two rotary cascade 15 tph driers. The centrifugal was commissioned by Five Cail during the period 18 to 30 November 2002, and was handed over to the refinery for evaluation. The centrifugal has been running continuously since then with the operating parameters recommended by Five Cail.

Normal operations

During normal operation of the centrifugal, samples of the refined sugar leaving the centrifugal were analysed for colour (every two hours) and moisture (every eight hours). Data such as centrifugal speed and temperatures were also recorded on an hourly basis.

Optimisations tests

- *Centrifugal performance* – Due to the extreme difficulty in arriving at accurate sucrose balances in high purity refinery products, impurity balances (conductivity ash and colour) are generally carried out in refineries to assess performance. For the centrifugal performance tests, conductivity ash and colour balance were therefore undertaken. The centrifugal yield, which is the mass of brix in sugar percent the mass of brix in massecuite, is given by equations 1 (based on ash) and 2 (based on colour).

$$\text{Centrifugal yield} = \frac{\text{\% conductivity ash (on brix) of jet} - \text{\% conductivity ash (on brix) of massecuite}}{\text{\% conductivity ash (on brix) of jet} - \text{\% conductivity ash (on brix) of refined sugar}} \times 100\% \qquad (1)$$

$$\text{Centrifugal yield} = \frac{\text{colour of jet} - \text{colour of massecuite}}{\text{colour of jet} - \text{colour of refined sugar}} \times 100\% \qquad (2)$$

For these tests samples of massecuite, jet and refined sugar were taken from both the continuous and batch centrifugals and analysed for conductivity ash, colour and brix.

- *Massecuite throughput tests* – The massecuite throughputs were calculated by doing brix balances across the centrifugal. This was done by two methods, *viz*. brix balances using molasses flow rates and sugar yields (equation 3) and brix balances using molasses and wash water rates (Hubbard and Love, 1998) (equation 4).

$$\text{Massecuite throughput (tph)} = \text{Tons jet} \times (\text{brix \% jet}) \times \frac{100}{100 - \text{yield \%}} \times \frac{100}{\text{brix \% massecuite}} \qquad (3)$$

$$\text{Massecuite throughput (tph)} = \frac{\text{Tons jet } (1 - (\text{brix \% jet} / 100 - \text{moisture \% sugar})) - \text{tons moisture}}{(1 - (\text{brix \% massecuite} / (100 - \text{\% moisture \% sugar}))} \qquad (4)$$

This entailed diverting and weighing the jet on a two ton electronic mass meter over a period of three minutes. During this period samples of massecuite, jet and sugar were taken and analysed for colour, conductivity ash, brix and moisture.

Analytical methods

All liquors were analysed according to the methods given in a laboratory manual (Anon, 1985). For the grain size analysis, because the sugar leaving the centrifugal was wet, it was washed with alcohol, as proposed by Wong Sak Hoi and de Rosnay (1996).

Results and discussion

Normal operations

The initial tests were done on first refined massecuites. The quality of the massecuite feeding the centrifugal was monitored, and the results are given in Table 1.

Table 1. Quality of first refined massecuite.

Parameter	Average value (std deviation)
% brix	89,5 (0,8)
Colour	344 (62)
% conductivity ash	0,17 (0,02)
Temperature	85°C

The results in Table 1 show that the quality of the massecuite varied considerably. This is expected, as the quality of incoming raw sugar can vary significantly. The massecuite feeding the centrifugals is generally higher in temperature (85°C) than other refineries and is due to steam of higher pressure (400 kPa) being used in the vacuum pans.

During normal operations, the continuous centrifugal was operated with the parameters recommended by Five Cail, which were:

- Massecuite throughput 40 tph
- Basket speed 820 rpm
- Crystal disperser speed 180 rpm
- Basket wash 2,7% on massecuite (20 L/min)
- Top wash 0,6 L/min
- Steam added to basket.

During the optimisation tests these parameters were varied, with the objective of improving the refined sugar quality in terms of colour and moisture.

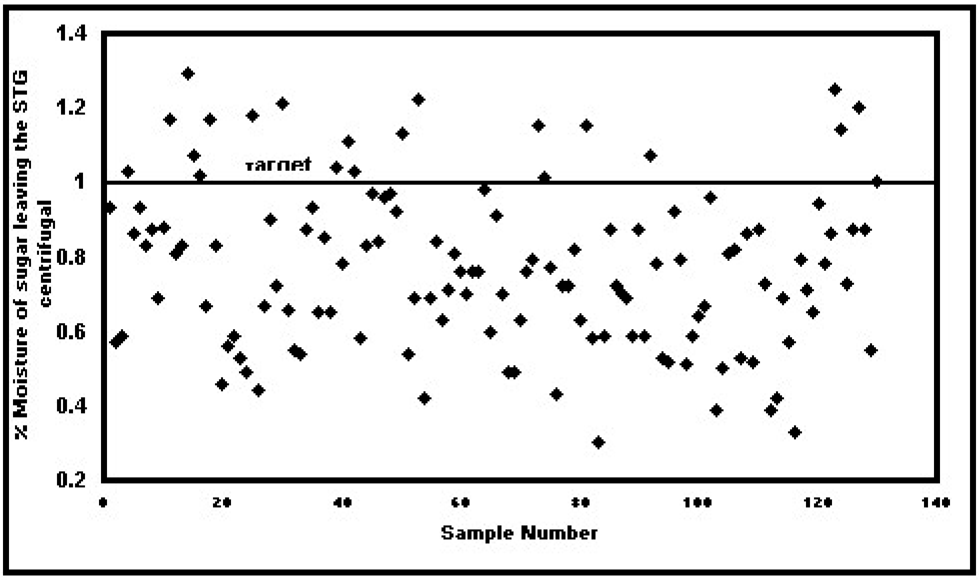

Figure 3. Percentage moisture of the first sugar leaving the STG centrifugal.

First sugar moistures

The STG continuously cured first refined massecuite for the period 30 November 2002 to 24 March 2003. The performance of the continuous centrifugal was monitored and compared with the adjacent BMA batch centrifugal, which cured similar massecuite. During these tests on the continuous centrifugal the amount of wash water added was 2,7% on massecuite, which was higher than that of the batch centrifugal (<1%). The moisture content of the sugars leaving the continuous and batch centrifugals are plotted in Figures 3 and 4 respectively.

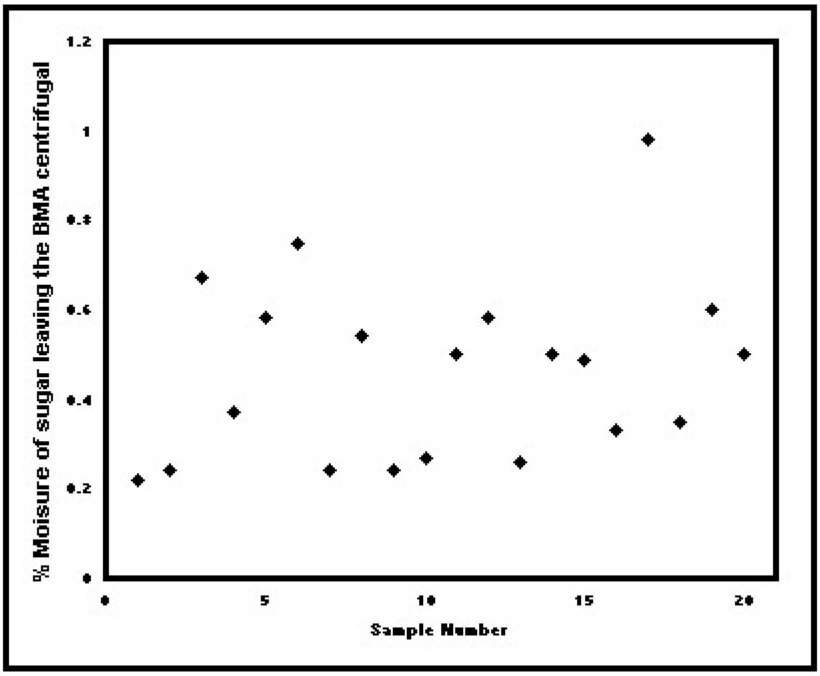

Figure 4. Percentage moisture of the first sugar leaving the batch centrifugal.

The results in Figure 3 show that for most of the trial the moisture value was less than 1% (average 0,77%, min 0,30 and max 1,29). However, it was observed that whenever the centrifugal was processing poor quality massecuite (in terms of crystal quality), the moisture values tended to increase. The moisture of the sugar leaving the batch centrifugal was generally less than 0,5% (average 0,46%, min 0,22 and max 0,98). When comparing the performance of the STG continuous centrifugal and the batch centrifugal in terms of sugar moisture, it can be seen that the moisture value of the continuous centrifugal is about twice that of the batch machine. This is expected, as the wash water rate of the continuous centrifugal is far higher than that of the batch centrifugal.

First sugar colours

The first refined sugar colour at the refinery is generally about 22 and can vary between 16 and 36 (2002 season), depending on the quality of incoming raw sugar. The colour of the first refined sugar leaving the STG continuous and batch centrifugals are plotted in Figure 5.

The average colour of the sugar from the STG centrifugal was 22 (min 8 and max 30), and the average sugar colour from the batch machine was also 22 (min 13 and max 33). The results (t test) indicate no significant difference between the sugar colour results of the STG and the batch centrifugals at the 95% level of confidence.

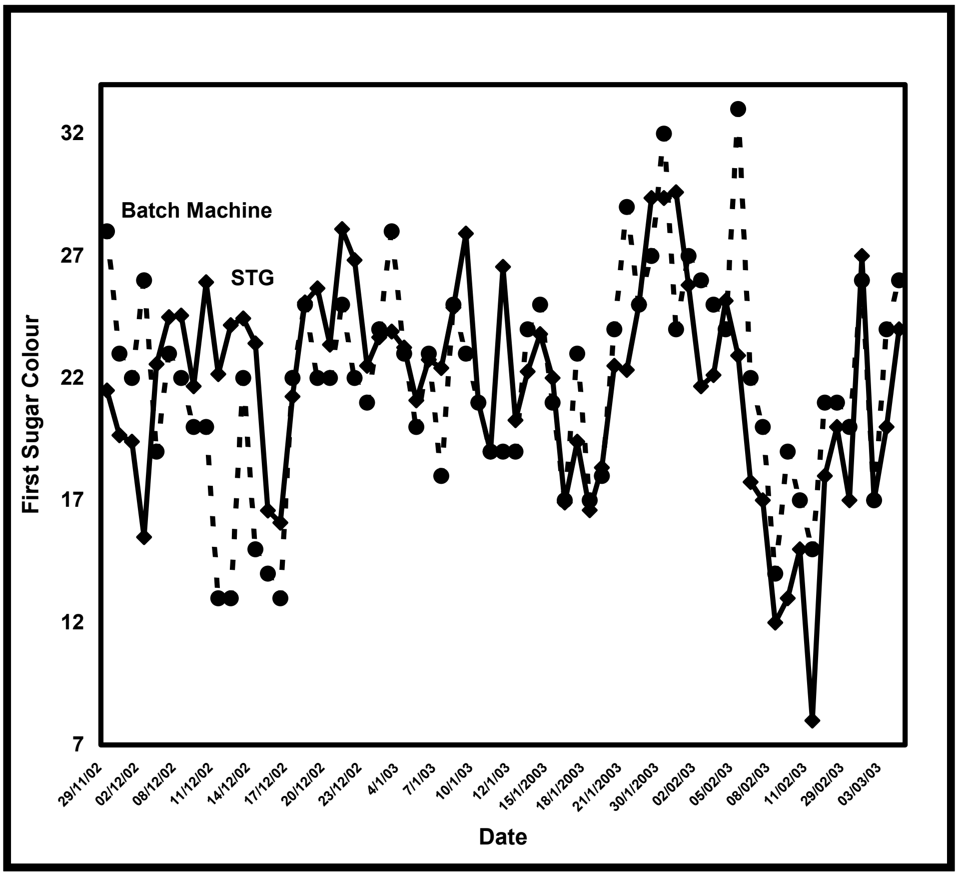

Figure 5. Colour results of the STG continuous and batch centrifugals.

Centrifugal yield tests

The centrifugal yields (mass of brix in sugar percent mass of brix in massecuite) were calculated by doing impurity (conductivity ash and colour) balances across the centrifugals. The results showed that there was no significant difference in the yields calculated by using either conductivity ash or colour. Yields for the STG continuous and batch centrifugals are given in Figure 6.

The average yields for the STG and batch centrifugals were 52 and 48% respectively. This difference was not considered to be statically significant at the 95% level of confidence. Although the wash water rate for the STG centrifugal (2,7%) was higher than the batch machine (generally less than 1%), it is worth noting that there were no significant differences between the yields. This indicates that minimal crystal dissolution occurred in the STG continuous centrifugal, even at the higher wash water rates, when compared with the batch centrifugal. However, a 1,5 unit decrease in the brix of the jet was measured when compared with the batch centrifugal.

This is not a cause for concern, because the refinery jets are generally ‘de-brixed’ to a value of about 75 before the next stage of crystallisation.

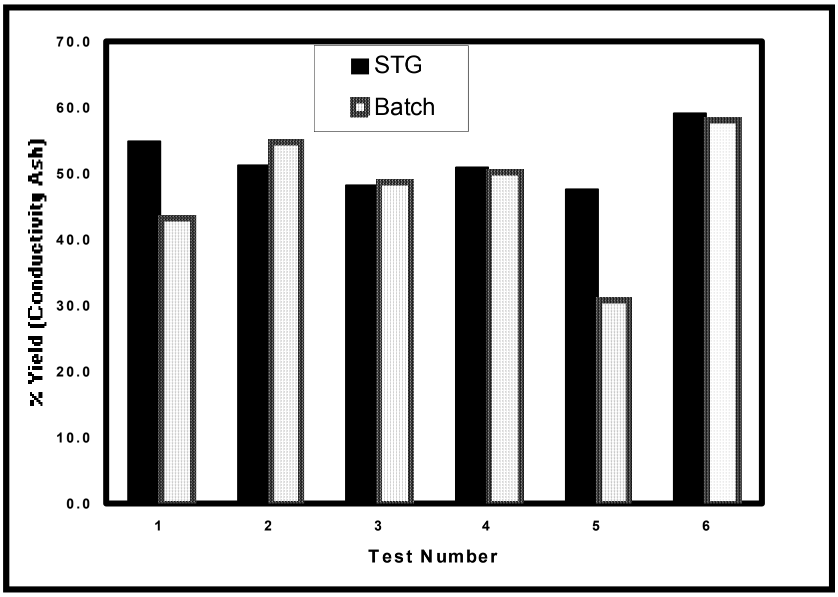

Figure 6. Comparison of the yields of the STG continuous and batch centrifugals.

Optimisation tests

Wash water optimisation tests

The effect of wash water rate on the colour of the sugar was investigated on different massecuite flow rates. The amount of water added varied from 1,0 to 5,0% on massecuite.

The results of tests done at a massecuite flow rate of 45 tph are given in Figure 7.

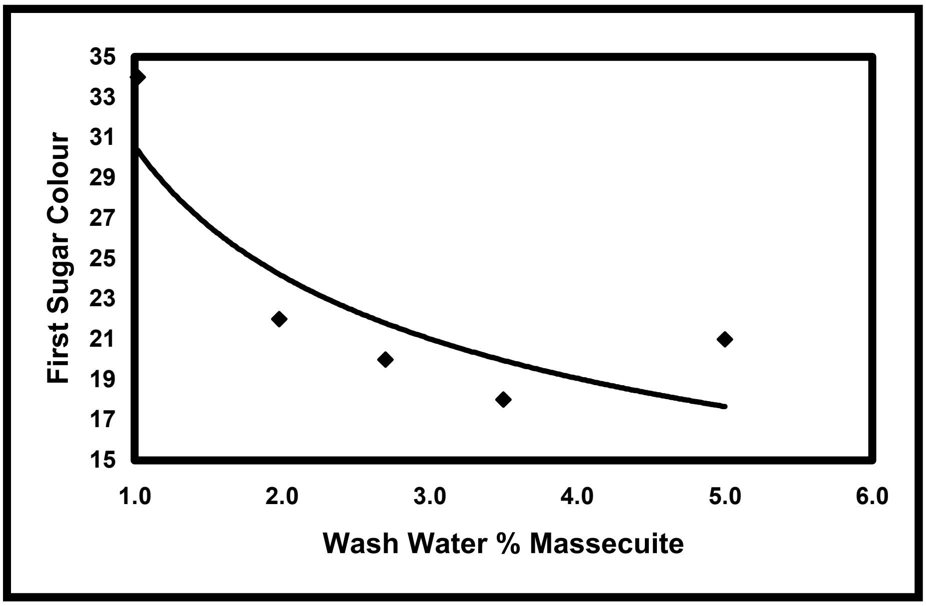

Figure 7. Wash water versus sugar colour for the STG centrifugal at 45 tph.

The results indicate that, as the wash water rate was increased from 1,0%, the refined sugar colour decreased from a value of 34 and, at the wash water rate of 3,5%, the lowest sugar colour of 18 was achieved. When the wash water was further increased to 5,0%, there was no improvement in the colour of the sugar.

The results of these tests confirm the findings of Greig *et al.* (1994), where it was shown that increasing the wash water rate decreased the colour of the sugar but no further improvement was measured when the water flow rate exceeded 20 L/min (2,7%). These tests indicated that the wash water rate should be between 2,5 and 3,5%, depending on the quality of the massecuite. Increasing the wash water does not have any major benefit on sugar quality.

The effect of wash water on the conductivity ash of the sugar was also measured and the trend was similar to the colour trend in Figure 7.

The effect of wash water on crystal dissolution was also evaluated. At the wash water rate of 1% the yield was 50,3%, and as the wash water was increased to 3,0% the yield decreased to 47%, indicating some crystal dissolution.

Throughput tests
The continuous STG centrifugal is driven by a hydraulic motor at a fixed speed. The power demand can be calculated from the hydraulic oil pressure, the hydraulic oil flow rate and the drive efficiency. A relationship was established by Greig *et al.* (1994) between the hydraulic oil pressure and the massecuite rate, by analysing the processing rate of the massecuite receivers. A correlation of the following form was established:

$$\text{Massecuite throughput (tph)} = (k_1 \text{ x } P \text{ (psi)} - k_2/\text{speed (rpm)} \qquad (5)$$

Approximately 100 trials were carried out by Greig *et al.* (1994) with varying massecuites and wash water rates to determine the capacity rating of the continuous centrifugal.

Tests were done to evaluate the throughput of the machine. For these tests, the throughput of the continuous centrifugal was varied from 26 to 54 tons per hour. The throughput measurements involved diverting and weighing the jet from the centrifugal for a period of three minutes. During this period, samples of massecuite, sugar and jet were analysed. The results from the analyses were then used to carry out brix, colour and conductivity ash balances. From these results the massecuite throughputs were calculated and compared with the throughput calculated using equation 5. The results of 18 tests done on first massecuites are given in Figure 8.

The results in Figure 8 indicate a fair correlation between the measured and the theoretical massecuite throughput.

The equation was as follows:

$$\text{Massecuite throughput (tph)} = 0{,}72 \text{ x PV (process variable) x } 10{,}7 \qquad (6)$$

$$n = 18, \quad r^2 = 0{,}66$$

The average difference between the measured and the theoretical throughput was about 5%. This was not considered significant for process control.

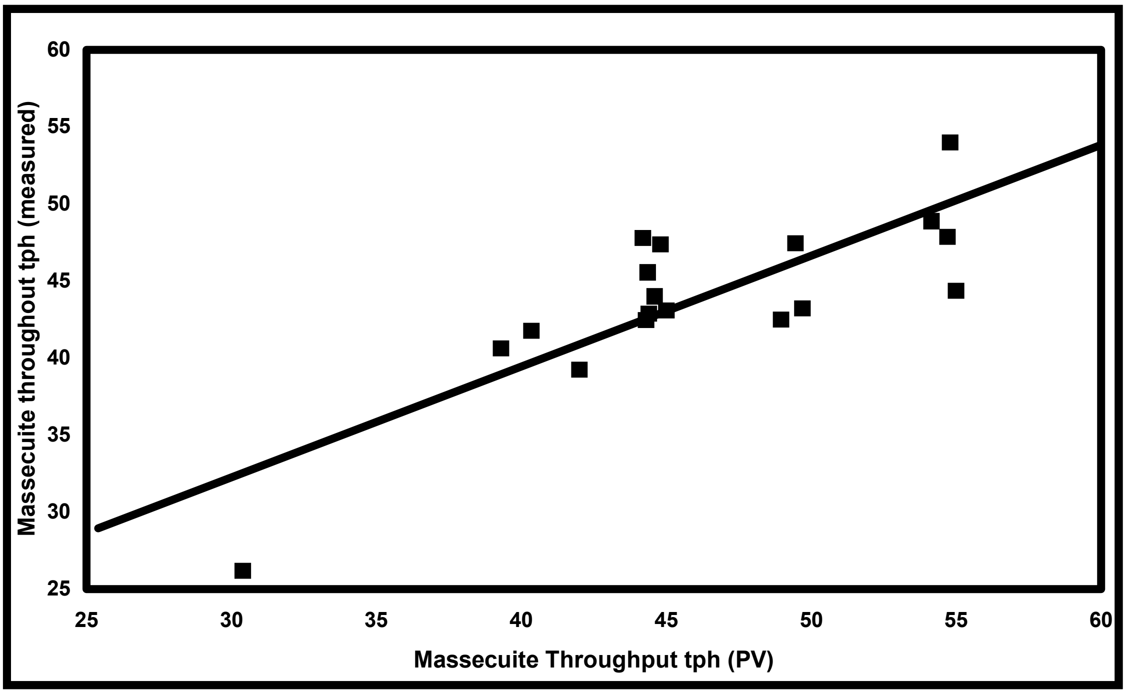

Figure 8. Comparison of measured and theoretical massecuite throughputs.

Sugar drying tests

Tests were done where the four batch machines were stopped, and only the STG was operated in that bay. For these tests the speed of the centrifugal was 820 rpm and the blender was operated at 180 rpm. Also, the steam addition to the basket was turned off. The sugar from the STG machine was then dried in two rotary cascade driers. The massecuite processed by the STG was varied from 25 to 55 tph and two wash water rates (2,7 and 3,5%) were evaluated. Samples of the massecuite, wet sugar from the centrifugals, jets and the sugar after the driers, were taken and analysed. The results of the analysis done on the samples taken at the centrifugal are given in Table 2.

Table 2. Analysis of samples taken at the STG centrifugal.

Date	Massecuite			Refined sugar (ex centrifugal)			Jet
	Throughput (tph)	Temperature °C	Water wash % massecuite	Colour	% moist	Temp	% brix
07/01/03	47	70	2,7%	38	1,29	76	78
07/01/03	43	70	3,5%	23	0,60	76	77
08/01/03	48	86	3,5%	43	1,38	76	76
09/01/03	26	85	2,7%	38	0,90	75	78
09/01/03	44	80	2,7%	20	0,76	75	78
09/01/03	54	84	3,5%	20	0,76	82	77
10/01/03	48	85	2,7%	25	1,13	77	79
10/01/03	44	89	3,5%	20	0,94	82	78

The following comments can be made regarding the results in Table 2:

- The temperature of the massecuite feeding the continuous centrifugal varied from 70 to 89°C.
- Although the steam addition to the centrifugal was turned off, the temperature of the sugar leaving the machine was above 74°C.
- For these tests the wash water rate of 2,7% did not produce the required sugar colour except on 09/01/03 at 44 tph throughput but when the wash water was increased to 3,5% the colour of the sugar in most cases improved to acceptable values.
- The moisture of the sugars leaving the centrifugal averaged 0,97 and varied from 0,60 to 1,38.

The results of the tests done on the samples taken after the driers, which processed the sugar from the STG and the batch machines, are given in Table 3. The moisture results of the sugars leaving the STG centrifugal and samples taken after the drier are plotted in Figure 9.

Table 3. Comparison of dried first refined sugars processed by the STG and the batch centrifugals.

Date	STG				Batch			
	% moist	MA (mm)	CV	% fines	% moist	MA (mm)	CV	% fines
07/01/03	0.07	0.71	37	12	0.03	0.56	37	16
07/01/03	0.02	0.69	44	15	0.03	0.56	40	19
08/01/03	0.03	0.75	33	7	0.03	0.69	35	9
09/01/03	0.08	0.67	36	11	0.04	0.64	39	13
09/01/03	0.03	0.65	40	14	0.03	0.60	35	14
10/01/03	0.05	0.56	38	17	0.03	0.49	37	22
10/01/03	0.04	0.55	36	19	0.04	0.51	38	19
Average	0.06	0.65	37	14	0.03	0.58	37	16

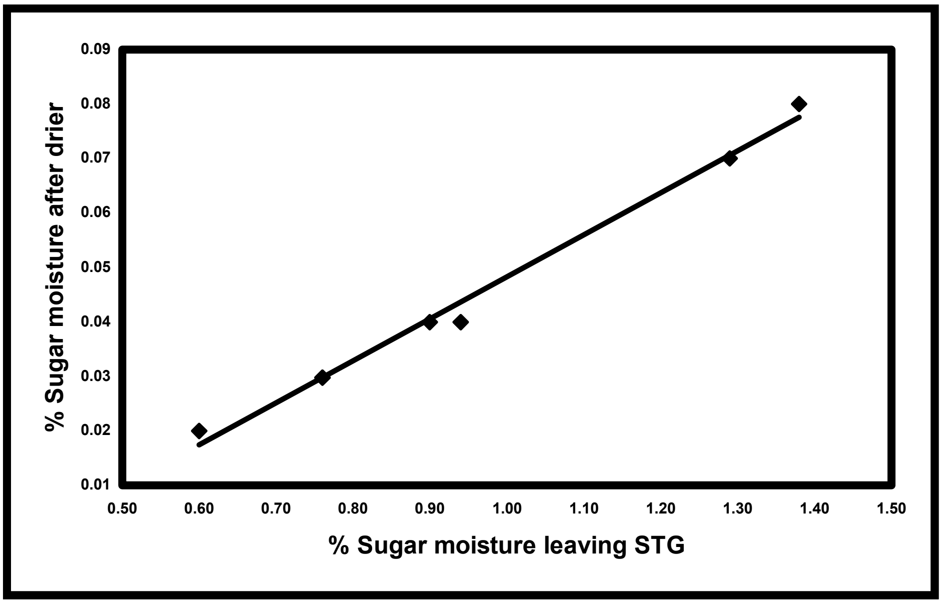

Figure 9. Comparison of the moisture values of the sugar samples taken after the STG centrifugal and after the driers.

As expected, there is a strong correlation between moisture results of the sugar leaving the STG centrifugal and the sugar leaving the drier. The results in Figure 9 show that for the current driers at the refinery to produce refined sugar with acceptable moistures, the moisture of the sugar leaving the STG continuous centrifugal should be <1%.

For these tests the moisture of the sugar leaving the STG machine varied from 0,60 to 1,38%, and moisture of the sugar leaving the driers varied from 0,02 to 0,08. Average sugar moisture from the batch centrifugal was 0,5%, and after drying it decreased to 0,03% (Table 3).

In terms of crystal quality, the sugar from both the batch and continuous centrifugal are similar. Photographs of the STG and batch machine sugar crystals are given in Figures 10 and 11, where comparison indicates no significant difference in the quality of the crystals.

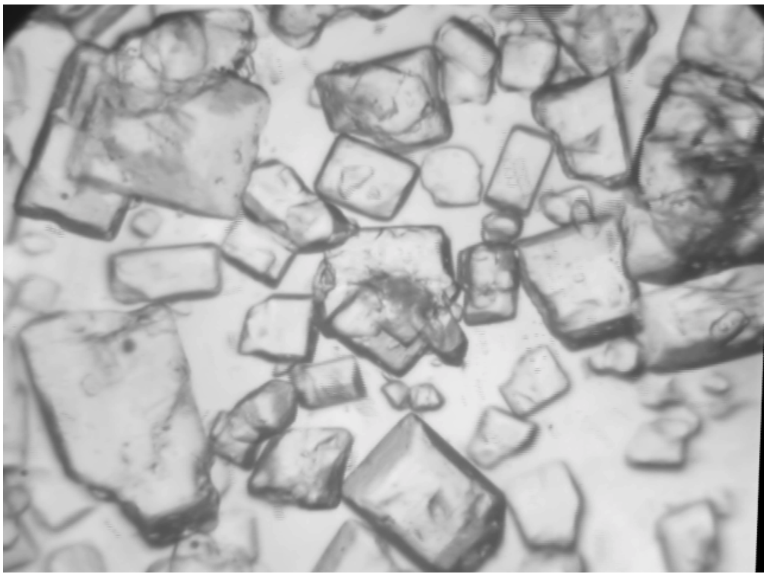

Figure 10. Sugar crystals from the batch centrifugal.

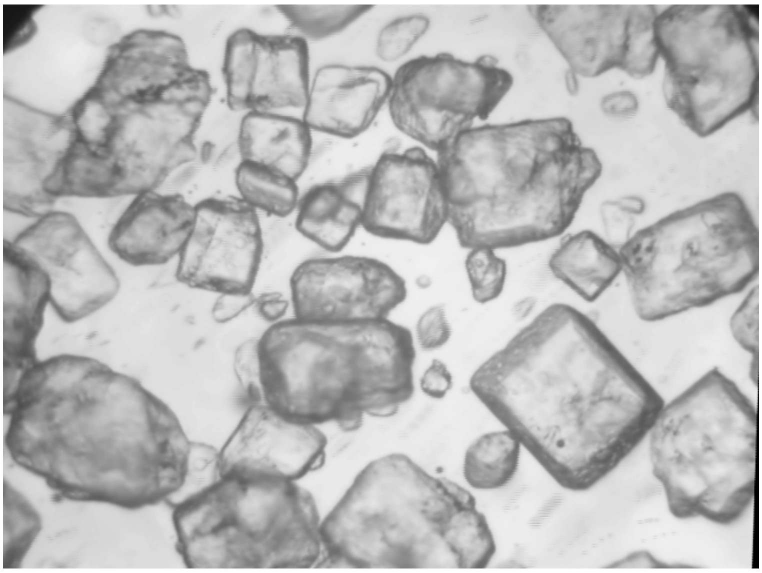

Figure 11. Sugar crystals from the STG continuous centrifugal.

Centrifugal speed tests

Tests were done where the speed of the centrifugal was varied from 840 to 880 rpm. For these tests the wash water rate was 2,7% on massecuite. During the tests, samples of the refined sugar were taken and analysed for colour, percentage moisture and crystal quality. The results showed that, as the speed of the centrifugal was increased from 840 to 880 rpm, the amount of fines in the sugar increased from 3,1 to 7,7% respectively. This indicates that some crystal damage occurred when the centrifugal speed was increased. The continuous centrifugal speed tests done on first refined massecuite showed that in terms of sugar quality the centrifugal should be operated at about 840 to 850 rpm.

Power consumption of the STG continuous centrifugal

A comparison (Table 4) of the power consumption of the batch and continuous centrifugals on A-massecuite was done by Grimwood *et al*., 2001.

Table 4. Comparison in power consumption of batch and continuous centrifugals (Grimwood *et al*., 2001).

Parameter	Typical old batch centrifugal	Typical new batch centrifugal	High grade continuous centrifugal
Throughput (tph)	12	30	30
Power consumption (kWh/T massecuite)	2,5	1,0	0,8

The figures in Table 4 show that power consumption of the high grade continuous centrifugal is lower than both the batch machines. The power consumption of the STG continuous on first refined massecuite averaged 0,48 kW/ton of massecuite and varied from 0,41 to 0,53 kW/ton of massecuite.

Tests on second refined massecuites

The results of tests done on second massecuites are given in Table 5. For these tests the centrifugal was operated at a speed of 850 rpm and the wash water rate was 3,7% on massecuite.

Table 5. Results of tests done on second massecuite.

Massecuite throughput (tph)	Sugar colour	% Sugar moist	% Yield
25	26	1,4	52
40	36	1,5	52
45	36	0,6	55

During the 2003/04 season, tests will be done on third massecuites.

Problems experienced during the trial

During the four month evaluation period the major mechanical problem experienced was vibration due to faulty screens. In addition, the vibration sensor failed and a new sensor had to be installed.

Conclusions

The results of the evaluation carried out on the STG high grade continuous centrifugal showed that the centrifugal can be used successfully to cure first and second refinery massecuites. When compared with the batch centrifugal, similar results were achieved in terms of sugar colour, massecuite yields and sugar crystal quality.

Although the moisture of the sugar leaving the continuous centrifugal was about twice that of the batch machine, the drier tests showed that, as long as the moisture was less than 1%, the sugar after the drier was within specification.

The main advantages of continuous high grade centrifugals when compared with batch centrifugals are:

- Lower power consumption
- Lower installed power
- Lower maintenance
- Lower cost (65% of batch)
- Improved sugar drier operations through improved feed to the drier.

The major difference between the high grade continuous centrifugal and the batch machine was the higher amount of wash water used in the continuous centrifugal. This resulted in the moisture of the sugar leaving the high grade centrifugal being almost twice that of the batch machine.

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