THE OPERATION AND PERFORMANCE OF CONTINUOUS CENTRIFUGALS

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ABSTRACT

Factors affecting the capacity of continuous centrifugals handling "C" massecuite are examined after the completion of several test runs on various machines at different factories. Feed pipe sizing, water addition and positioning, feed distribution, scaling of screens, etc., are discussed and recommendations made.

Introduction

For several years continuous centrifugals (typically BMA K850) operating on C massecuites in South Africa in the range of ± 9 000 P at 50°C have been rated at 1 200 kg/h (± 30 ft^3/h) and over 200 machines have been installed on this basis.

The discrepancy between local throughputs and those reported overseas were attributed to the supposedly exceptional viscosity and stickiness of SA massecuites. However a recent visit by Lamusse and FitzGerald[1] to Australia and Mauritius dispelled all illusions on this score as the viscosity of South African C massecuites lie within reported viscosity ranges from both these countries. As a result of this visit, the SMRI carried out an intensive investigation into the poor throughputs of local machines and the main points of investigation and the results thereof are summarized in this paper.

Installations examined and types of machines

Work was carried out at the following factories and the machine types are listed under each factory.

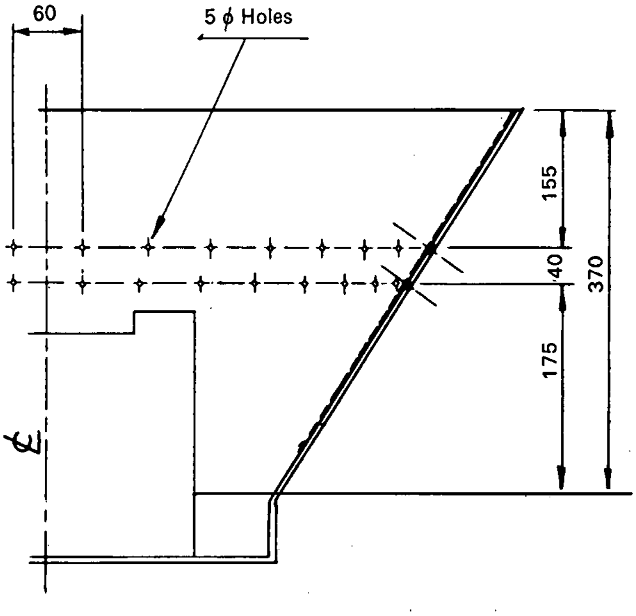

FIGURE 1 Detail of modification to BMA K850.

Darnall: Standard BMA K850 and a modified BMA K850. Modifications consisted of a speed increase from 2 200 rpm to 2 500 rpm and two rows of 5 mm holes (a total of 46) drilled into the basket. (Fig. 1) (this modified centrifugal is referred to as BMA No. 10 in the text table). One Fives Lille FC 1 000. This Fives Lille FC 1 000, was modified at a later stage by a speed increase from 1 900 rpm to 2 100 rpm.

Tongaat: BMA K850.

Sezela: BMA K850.

Melville: Western States CC-IV-(34" x 34°) basket.

The K850 and FC 1 000 are centre feed machines with solid baskets and the CC-IV-34 is a side feed type with perforated basket (Fig. 2).

Investigational aspects

During the course of the experiments the following points were investigated:

1. Flow of massecuite to the centrifugal in relation to (*a*) pipe and valve sizing, (*b*) viscosity, (*c*) height of massecuite above the delivery valve.
2. Massecuite distribution in the centrifugal.
3. Conditioning of massecuite.
4. Effect of spraying water and steam in the basket.
5. Molasses drainage and scaling of screens.
6. Capacity of continuous centrifugals.

Results and discussion

In order to compare the results of the different tests and reduce possible analytical and calculation errors, all the sampling and measurement procedures were standardised, and all the analyses were carried out at the SMRI. A Brookfield Viscometer Model RVF was used for viscosity measurements.

Flow of massecuite to the centrifugals

Early investigations showed that in most cases when viscosities were high, the limitation in throughput was caused by the inability to supply massecuite to the machine at the required rate.

Fig. 3 shows the effect of increasing valve opening on massecuite throughput, at different viscosity levels, through a standard 100 mm diameter iris valve. These tests were carried out at Sezela. One run was completed at Darnall.

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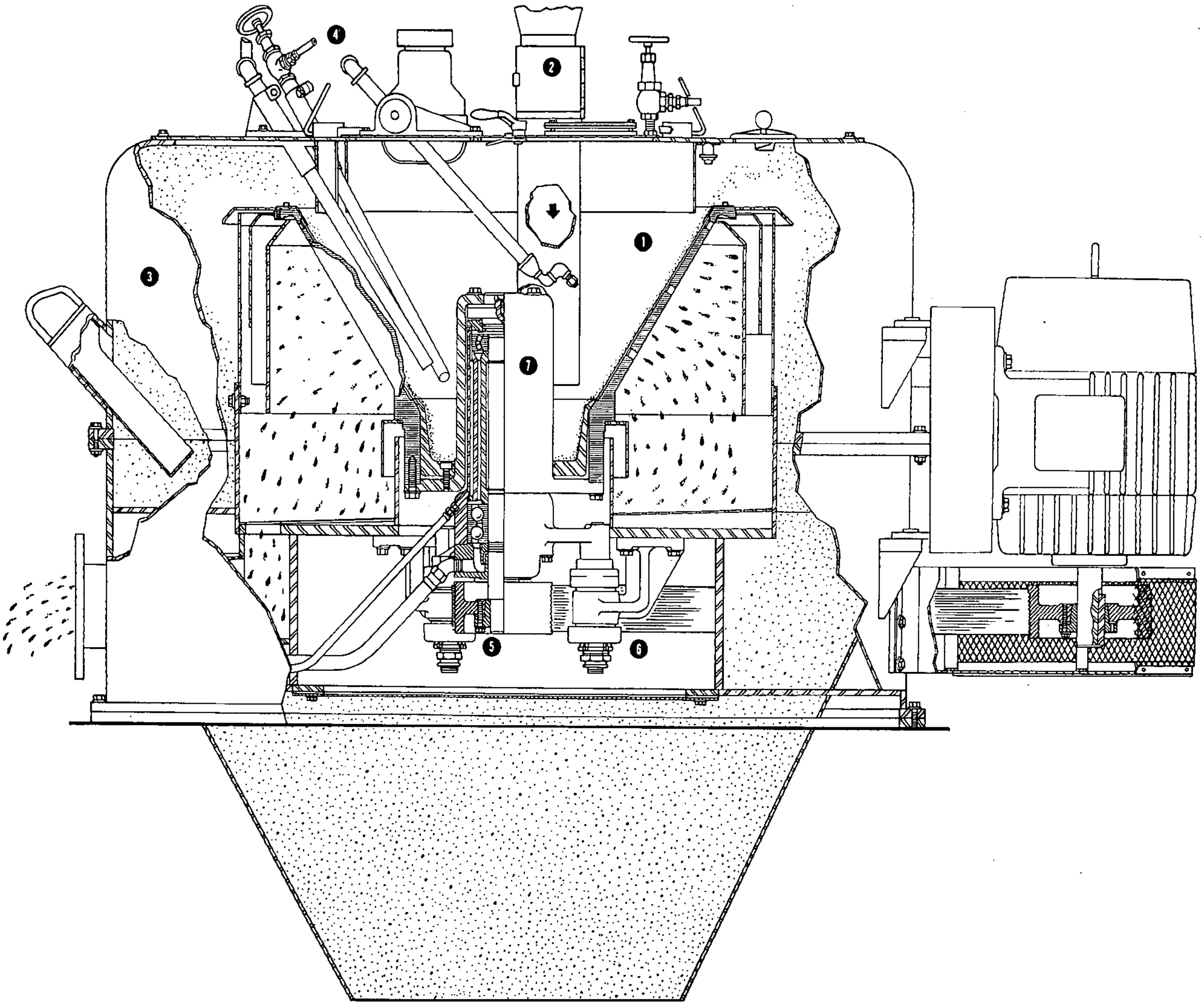


FIGURE 2 Side feed machine with perforated basket (CC-IV-34 Western States).

Capacity is about the same for massecuite of different viscosities at 25% valve open but variations in flow rate increase with wider valve opening. Grain size and concentration may also affect the flow properties of the massecuite although these were not measured. These two factors together with differences in head probably account for differences in flow rate at 25% valve opening.

The viscosities plotted were not high and throughputs increased with valve opening. These results must be compared with the following graphs in which flow rates reach a definite plateau and do not increase significantly despite further valve opening.

This effect of higher levels of viscosity vs. valve opening on throughput is illustrated in Fig. 4.

Line A is for a medium viscosity (9 000 P) while B is for a 12 000 P massecuite. The offset in line B at 40% valve opening and the scatter of points at 100% opening on line A indicate the effects of variation in head of massecuite and hence pipe friction on the feed rate. These tests were carried out on K850 machines with standard 100 mm iris valves. To overcome this restriction a 100 mm valve was replaced by a 150 mm valve and in addition a lubrication "rod" was fitted into the feed pipe.

This rod (a small-bore stainless steel pipe) enters the feed pipe above the iris valve and curves down along the pipe centre line through the centre of the iris valve to just clear of the flange. Four holes 0,5 mm are drilled into the pipe wall and the end of the pipe is sealed. A general view of the feed pipe is shown in Fig. 5.

The increase in capacity due to larger valve size alone is shown by curve C. The capacity increase for a more viscous massecuite (15 000 P at 60°C) at 100% valve opening was significant, the flow increasing from 700 kg/h to 1 700 kg/h. Later in the same test at 100% valve open, water was used for rod lubrication and the capacity increased from 1 700 kg/h to 2 150 kg/h. These points are labelled D, E and F in Fig. 4.

Another observation made was that there were large fluctuations in viscosity from day to day, sometimes even during the same day, and continuous observation and adjustments of feed to the centrifugals is therefore a necessity. (Refer Table I)

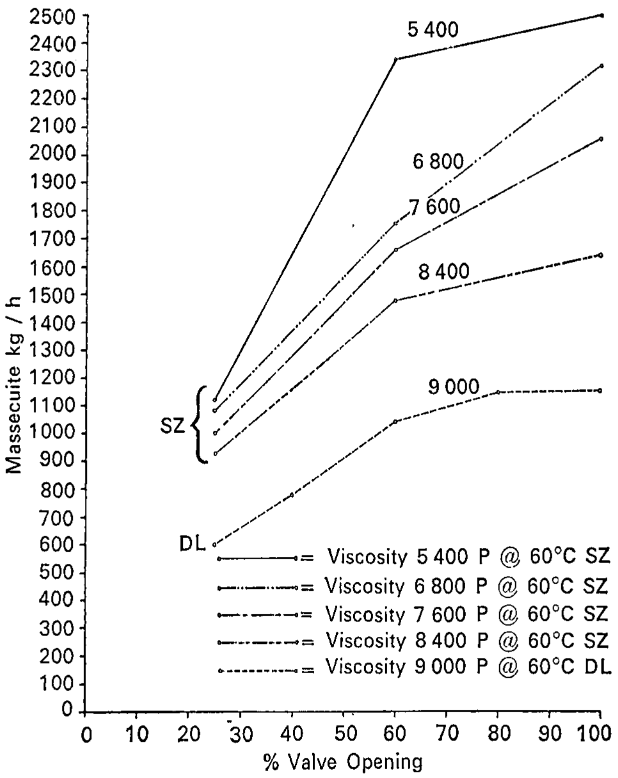


FIGURE 3 Massecuite throughput at different viscosities against percentage valve opening.

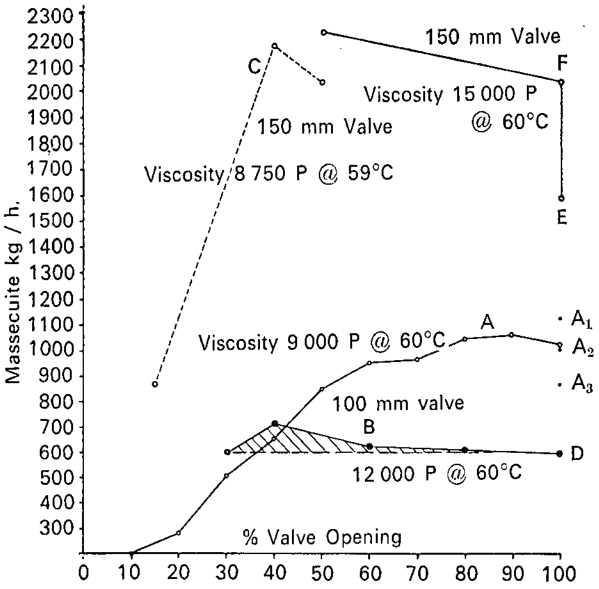


FIGURE 4 Massecuite throughput at high viscosity levels against percentage valve opening.

Massecuite distribution in centrifugal

The efficiency and capacity of a continuous centrifugal depend to a large extent on even distribution of massecuite on to the screen in order to be able to use the whole effective screen area. The centrifugals tested were fitted with two types of distributors: the *centre feed* and the *side feed.*

The centre feed is typical of the BMA K850 and the Fives Lille FC 1000, the side feed is used in the Western States machine. From a mechanical engineering point of view, centre feed is preferable and centrifugals fed through the centre are less liable to vibration but the main disadvantage is uneven distribution of the massecuite. The distributing unit consists of a cylindrical distribution cup with several distributing pins (4 or 8) and an acceleration cone. This cone is bolted to the distributing cup by vertical pins in the case of the BMA and six impellers for the FC 1000. Even under the best conditions, spread of massecuite distribution looks like a series of fingers spreading from the bottom to the top of the basket (Fig. 6).

It was found that the finger effect on to the screens was mainly caused by erratic surges in massecuite from the accelerating cone which either strike the screen directly or hit the top part of the screen clamping cup. It appears that these localised surges or lobes of massecuite that speed up the basket without being purged are related to the number of bolts that support the accelerating bell in the BMA or the number of impellers in the case of the Fives Lille. This finger effect becomes greater as the lubrication water to massecuite ratio increases.

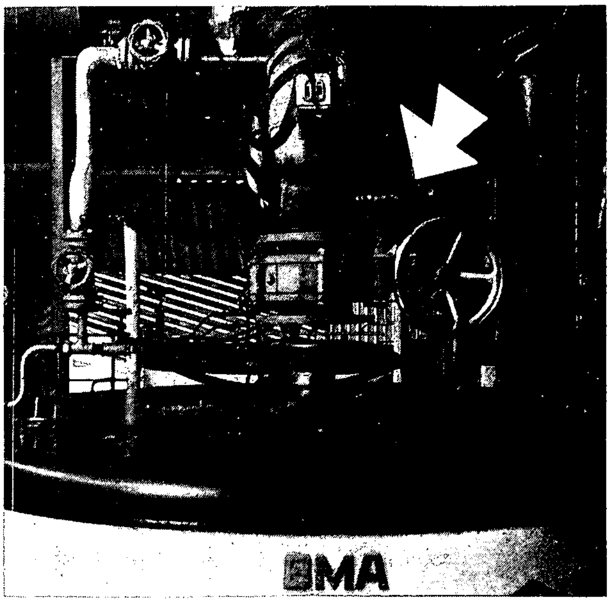


FIGURE 5 View of feed pipe showing lubrication "rod" and 150 mm iris valve.

TABLE I

Test	Time	Viscosity in poise	Temp °C
A	11.00 a.m.	5 200	50
	1.00 p.m.	3 700	50
	3.00 p.m.	3 800	50
	10.00 a.m.	2 500	50
B	12.00 noon	5 300	50
	12.45 p.m.	4 500	50

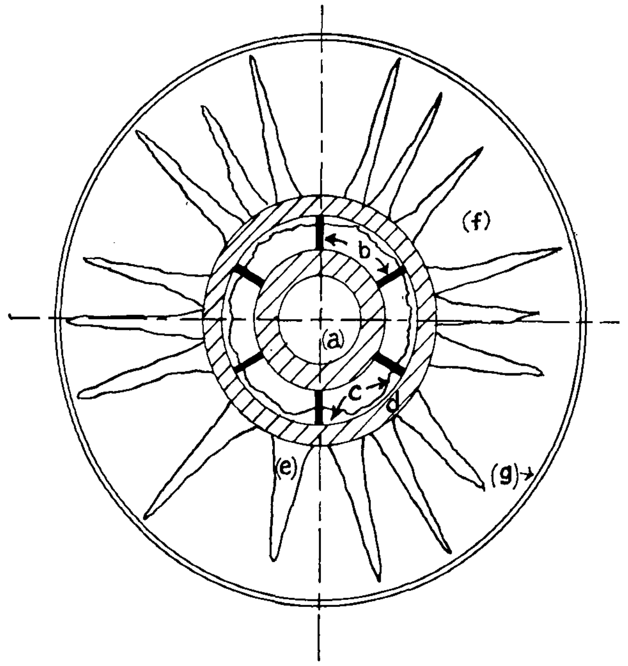


FIGURE 6 Massecuite distribution from centre feed machine.
(*a*) Acceleration cup with inflow of massecuite
(*b*) Web impeding flow of massecuite to basket
(*c*) Massecuite on the inside of the feed cone
(*d*) Feed cone down which massecuite moves to basket
(*e*) High speed lobes of massecuite
(*f*) Purged sugar
(*g*) Basket rim.

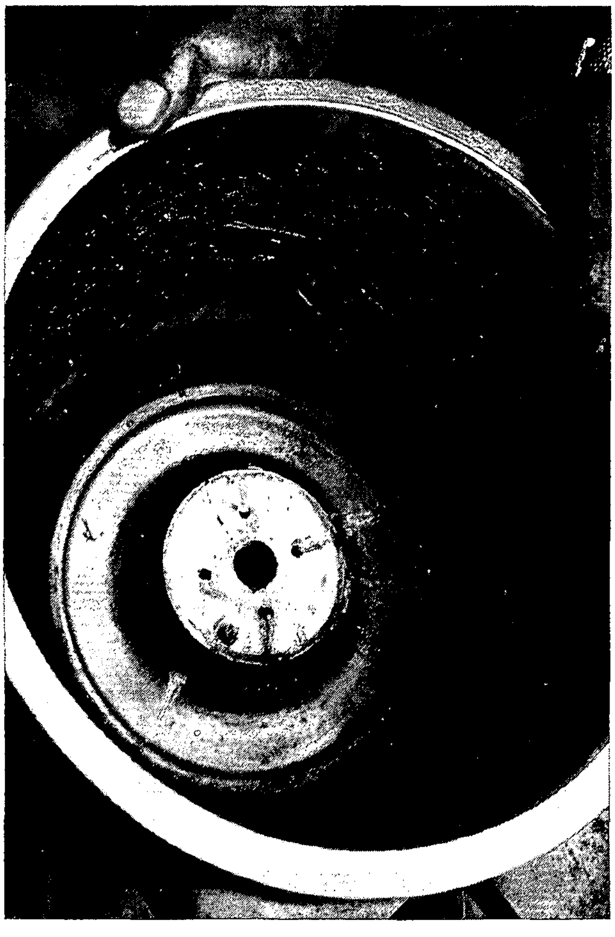


FIGURE 7 Scaling on the inside of an accelerating cone.

The side feed machine on the other hand can show perfect massecuite distribution under the stroboscope when properly fed and the effect of adjustment of massecuite flow rate and/or lubrication water can be easily observed and controlled. By working on a colour line width the required purity of the sugar can be pre-set.

Another advantage of the side feed machine is that it cleans itself of pieces of scale and other solid impurities in the massecuite. These collect in the accelerating cone or distributing cup of the centre feed machines and further prevent proper distribution of massecuite (Figs. 7 and 8).

It has been observed that an acceleration cone can scale-up to such an extent that 24 hours after cleaning an estimated 10 to 20% of the basket does not receive massecuite and there is therefore a drop in throughput.

At SZ the capacity of a BMA machine was doubled for the same sugar purity with no apparent rise in resultant molasses purity by changing to a different type of accelerating cone. Capacity increased from 960 to 2 100 kg/h of massecuite (Figs. 9 and 10).

It is suggested that the uneven feeding defects of these centre feed machines could be overcome by increasing the depth of the purging screen clamping cup and the length of the accelerating cone in the same proportion so as to give a greater solid surface to homogenise distribution on to the screens (Fig. 11).

A disadvantage of the side feed machine is that massecuite of high viscosity, say above 8 000 P at curing temperature, has a tendency to coil round the centre shaft and fragments of massecuite are thrown clear by centrifugal force without being purged. This, however, can be controlled by proper conditioning of the massecuite (Fig. 12).

Conditioning of massecuite

Just as flow of massecuite to the machine rather than the centrifugal itself has been found to be the limiting factor to capacity increase, the correct conditioning of massecuite is also more important than the type of centrifugal for performance.

The ratio of lubrication water to massecuite is critical for the centre feed machine. Too little water will not yield good sugar and too much water will hinder good distribution of massecuite on to the screens. It was observed that when too much water was used in the form of lubrication the massecuite appeared to ride over the water and purging was poor. It was also found that introduction of lubrication water coaxially through the centre guide rod (Figs. 5 and 13) was more effective than circumferential lubrication. It is believed that any conditioning of massecuite, apart from molasses dilution in the crystallizer if required, must be applied as late as possible before feeding into the centrifugal; in order to limit or prevent any substantial rise in resultant molasses purity.

Steam introduction into the massecuite stream also improves performance and the massecuite feed pipe below the valve to the centrifugal should be fitted with facilities for both water and steam addition. It has

FIGURE 8 Typical debris removed from continuous centrifugals. (scale: in inches)

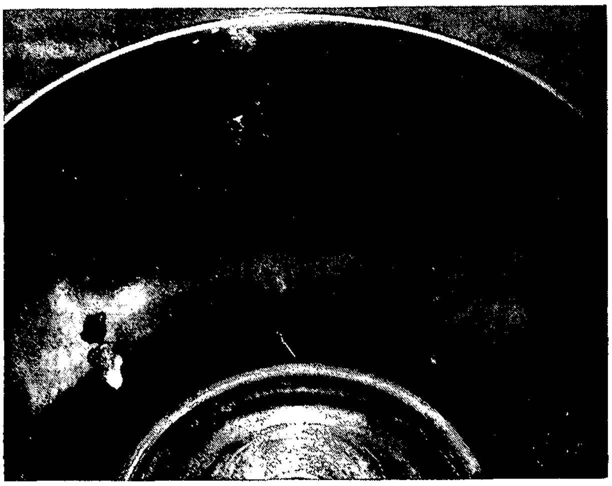


FIGURE 9 Previous design of accelerating cone.

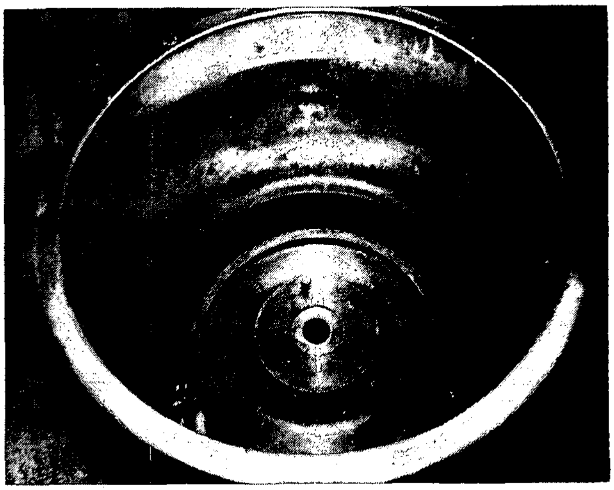


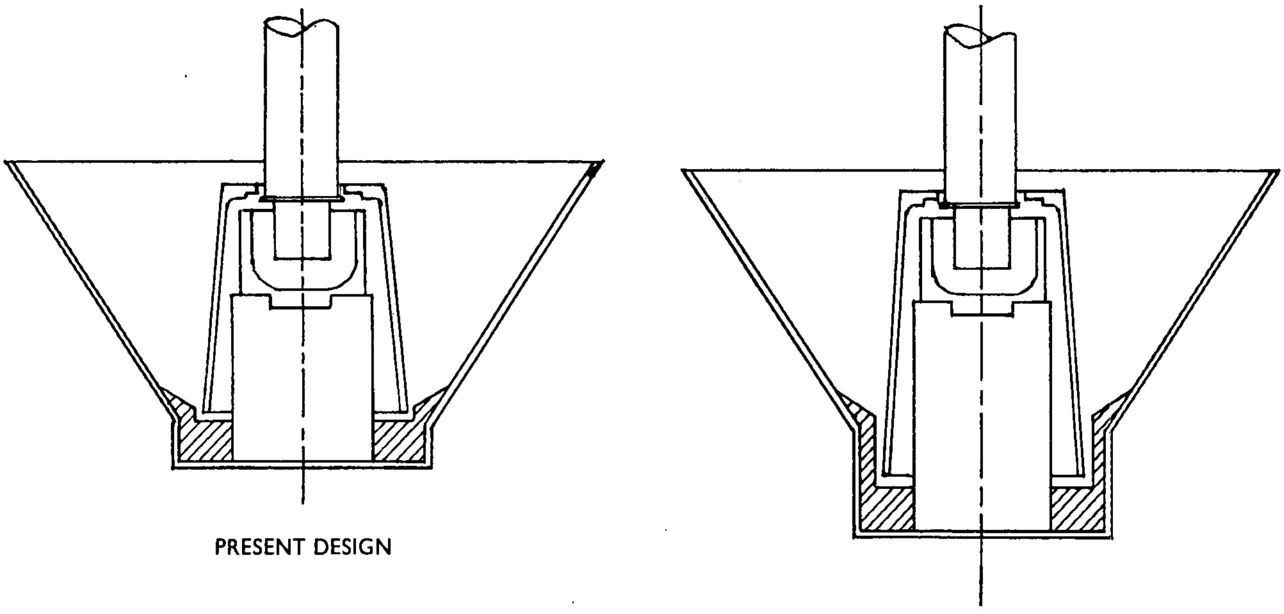
FIGURE 10 Improved design of accelerating cone.

also been found that by increasing steam pressure (up to 2 bar) in this feed compartment, purging is improved considerably and in so doing the amount of water required can be reduced. Reduction of the water to massecuite ratio enables production of a higher brix molasses and this may be of importance if molasses has to be sold at 80° brix or above.

Washing with water and steam in the basket

Both steam and water or heated water were found to be effective in improving sugar quality when applied vertically on the solid part of the screen clamping cup (Fig. 14) or alternatively, in the case of the centre feed, at the point where the massecuite leaves the accelerating cone and immediately before it reaches the basket. Best results were obtained with steam at 1 bar pressure or lower.

The nozzle for steam and water washing should be mounted very close to the basket to prevent any of the atomized spray from being blown to the top of the basket by air turbulence and hence producing wet sugar with condensation and dripping in the sugar compartment.



PRESENT DESIGN

PROPOSED DESIGN.

FIGURE 11 Proposed design for improving massecuite distribution on centre feed machines.

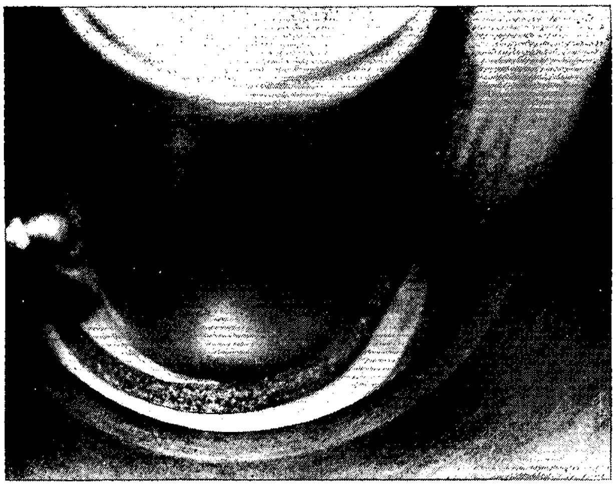


FIGURE 12 Massecuite feed on side feed machine.

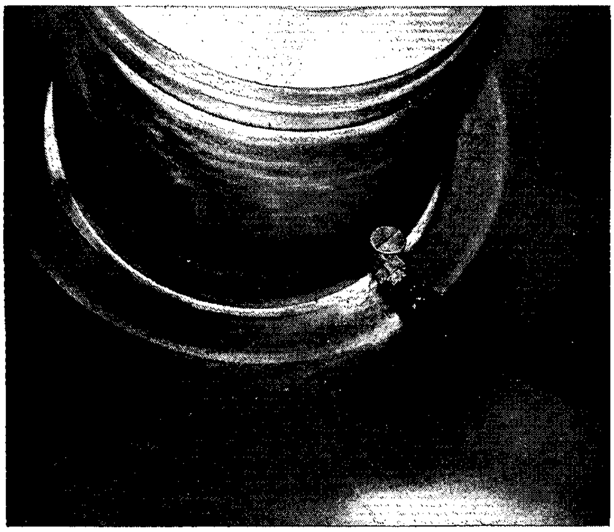


FIGURE 14 Water spray on to vertical wall of screen clamping cup.

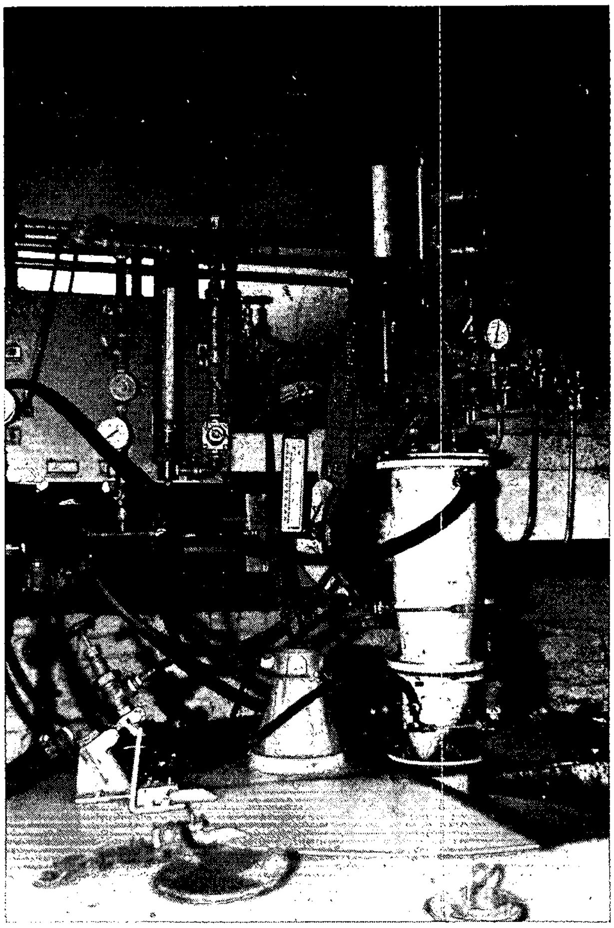
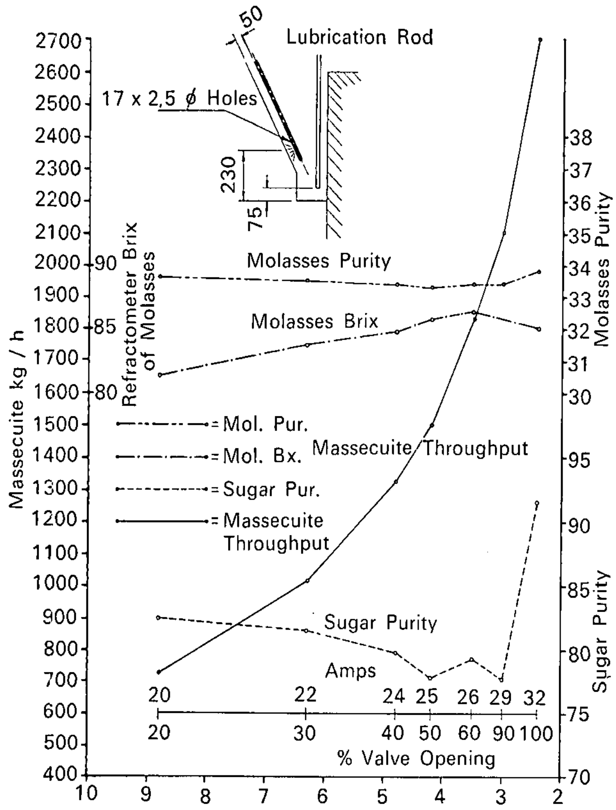


FIGURE 13 Experimental feed pipe equipped with lubrication points, both circumferential and co-axial.



Effect of Lubrication Water and Steam on Sugar and Molasses Purity

FIGURE 15 Water to massecuite ratio tests on Western States machines at Melville.

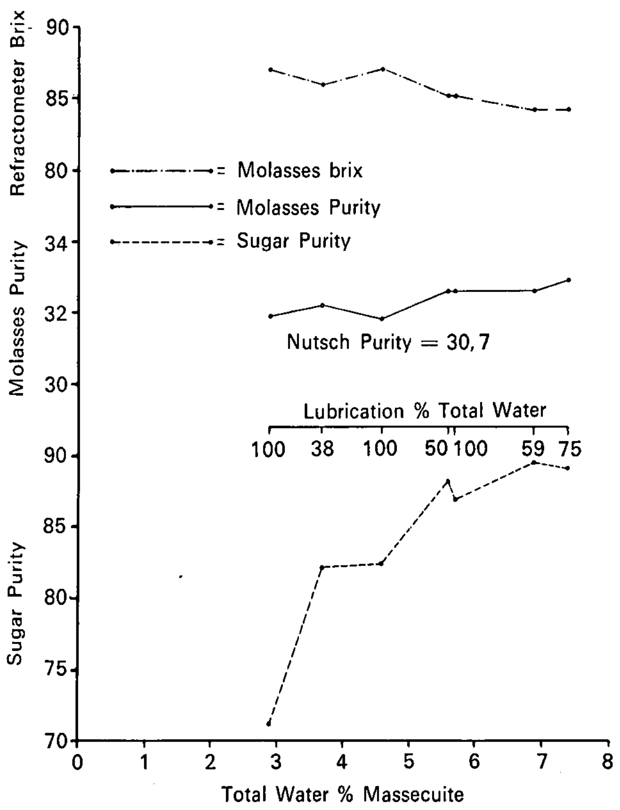


FIGURE 16 Water to massecuite ratio tests of varying lubrication and spray water proportions on BMA K850.

Figure 15 illustrates a series of tests carried out at Melville on the Western States machines with different water to massecuite ratios. The lubrication water was kept constant and the throughput was increased until the sugar quality became unacceptable (77° purity). Steam was then used and for the same amount of water added, at a capacity of 2 700 kg/h, sugar purity rose by 13,9° from 77,7 to 91,6 for only a 0,6° rise in molasses purity. The power consumed is also recorded against the valve opening.

Figure 16 illustrates the effects of lubrication and spray water in different proportions and varying water to massecuite ratios on sugar and molasses purity. It shows that limited water spraying increased the sugar purity significantly with only a slight increase in molasses purity. This purity rise in molasses occurs when the sugar purity exceeds 83 and then levels off until the purity reaches 89. The increase in sugar purity is the result of a higher water to massecuite ratio. At 4,6% water on massecuite, molasses purity rise is only 1,1, but when the ratio reaches 6,9 the corresponding rise is 1,9 and a further rise of 0,3 in purity is reached at higher ratios.

During the tests, it was found that the grain size of the massecuite together with the viscosity had an important effect on the water to massecuite ratio required for a given sugar and molasses purity. However, the effect of grain has not been examined in detail.

Molasses drainage and scaling of screen

Another factor of great importance for optimum performance of continuous centrifugals is the drainage of molasses from the basket and the cleanliness of the screens. Previous mention has already been made of scaling in the acceleration cone.

During the tests it was found that rapid drainage of molasses from the basket was critical. This was observed under stroboscopic light from the purging pattern of the massecuite over the screens of both the solid and perforated baskets and this effect is related to the rate of scaling of backing and purging screens.

During the tests, the screens were examined regularly and it was found that solid basket screens (BMA and FC 1000) were fouling at a very fast rate while the perforated basket screens (Western States) were not scaling at all.

Figure 17 illustrates the difference between a clean and a fouled BMA screen after three weeks of continuous operation and Fig. 18 is a close-up of the dirty screen. It shows that the highest concentrations of scaling were at points of no or partial drainage, that is: at screen overlaps or where they are clamped at the bottom of the cup and at the top of the basket. It was also found that the backing screen was fouled, but to a lesser extent, by a soft scale which would not dissolve after a good wash with hot water through the purging screen.

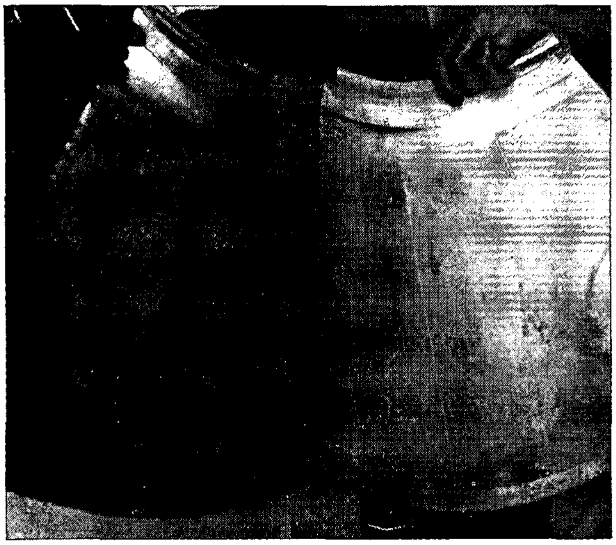


FIGURE 17 Comparison of clean and fouled screens.

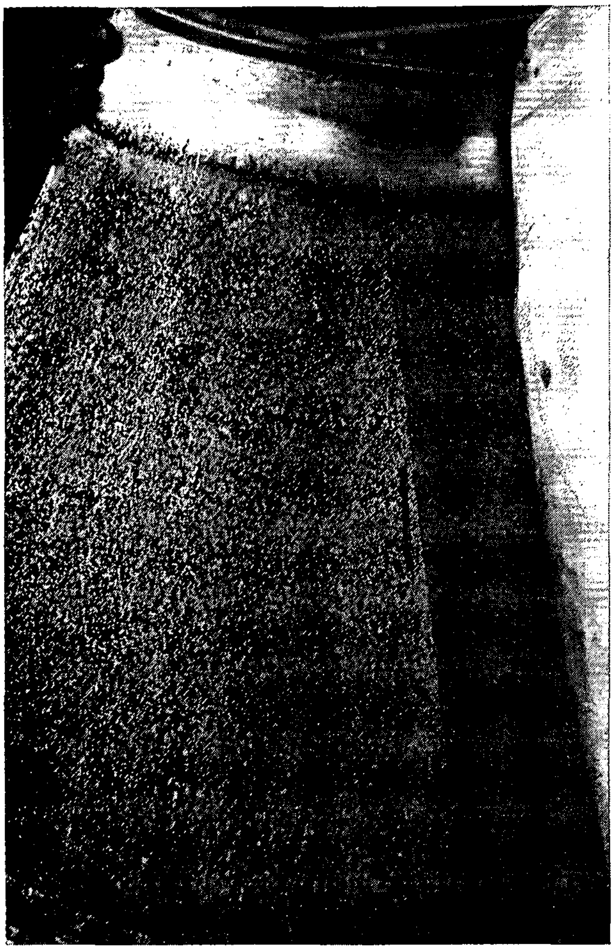


FIGURE 18 Close-up of fouled screen.

Figure 19 shows the open area of a FC 1000 screen after three weeks of operation. This picture is of the middle part of the screen, in other words the least scaled-up area. Of a total of 180 slots there are 43 slots partly or completely obstructed, which represents a reduction in drainage area of about 24 %. This figure could be conservative in some cases or over-rated in others but gives a dimension to the scaling problem. One hour every two weeks is a typical cleaning schedule but a definite cleaning schedule related to the scaling at a particular mill is required.

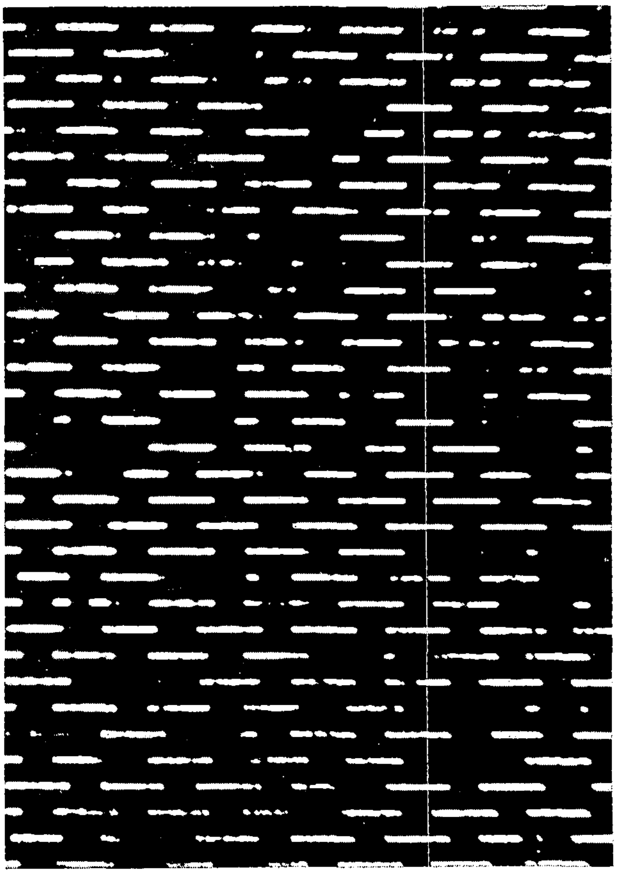


FIGURE 19 Basket screen after three weeks' operation. Approximate loss of drainage area 24%.

Capacity of continuous centrifugals

The capacity of continuous centrifugals depends primarily on the sugar purity required. It is, however, possible by proper attention to preconditioning of massecuite, cleanliness of screens and maintenance of the acceleration cone, to increase capacity on existing machines without affecting either the target sugar purity or the existing molasses purity rise across the machine.

Measurement of capacity is not easy but it can either be done (in BMA only) by collecting massecuite directly in a tray or by weighing molasses produced in a given time and calculating the weight of massecuite by brix or pol balance.

When the weight is calculated by mass balance, compensation has to be made for the total water added to the massecuite, usually measured by means of a rotameter. The weight of massecuite is calculated as follows:

$$\text{Wt. of massecuite/hour} = \text{Wt. of run-off/hour} - \text{Total wt. of water added/hour}$$
$$\times \left[\frac{\text{Pol sugar} - \text{corrected pol molasses}}{\text{Pol sugar} - \text{pol massecuite}}\right].$$

Some high-capacity runs are shown in Table 2 but they do not necessarily coincide with optimum massecuite conditioning. The first line indicates current accepted South African throughputs with a standard machine.

Considerable time was spent on conducting capacity test runs at Darnall and these are reported in Tables 3 and 4. During these tests, all the standard BMA machines were working at 100% valve opening, and the massecuite viscosity remained steady at 8 500 P at 59°C. Referring to Fig. 4, line A, it will be noted that a BMA capacity with the 100 mm iris valve at 9 000 P and 100% valve opening was around 1 100 kg/h.

Run A_1 shows comparative results between the FC 1000, working at high and low capacities at 1 900 rpm and composite samples from BMA machines working under normal factory conditions. Molasses purities are almost equal. It should be noted that the two low capacities (1 260 and 1 446 kg/h) were measured when the machine was under control of the factory operator and they illustrate the tendency of operators to throttle the feed. In run A_2 the FC 1 000 speed was increased to 2 100 rpm and the tests were carried out at 100% valve opening over an 8-hour period. It is apparent that the speed increase had the positive effect of nearly doubling the capacity for a 0,3 lower purity drop across the machine and still giving an average final molasses purity of 0,3 lower than the standard BMA working under control of the factory operator and producing sugar of approximately the same purity.

The average of results obtained with the FC 1 000, shows that without taking massecuite viscosity into consideration this centrifugal averaged 3 080 kg/h during the period under tests for a 2,4 difference between molasses and nutsch purity. Molasses purity was 0,4° lower than the factory-operated machines for the same comparative period.

TABLE 2

Surface area of screens. m²	
FC 1 000	= 1,145
BMA K850	= 0,756
Western States	= 0,847

Since the FLC 1 000 and BMA K850 are very similar in design these results indicate the influence of screen area on capacity as the FLC 1 000 has a screen area of 1,145 m² as compared to 0,756 m² for the BMA K850.

Results of run B listed in Table 4 were carried out in parallel to runs A_1 and A_2 but with the modified (No. 10) BMA K850. This machine performed very well and reached a throughput of up to 2 766 kg/h with molasses purity that was approximately the same as that from standard K850. The average results of run B show that with a slightly modified machine and better operation a 60% increase in capacity could be achieved for a lower molasses purity. However, one must bear in mind that the modified BMA was always operating under optimum conditions.

Conclusions

From the observations made during the running of these tests, the following conclusions can be drawn:

1. For high viscosity massecuites adequately sized massecuite piping and feed valves are essential to achieve constant flow to the machine. The head of massecuite above the machine must also be taken into consideration. It is recommended that the diameter of the vertical feed pipe feeding a continuous centrifugal should be at least 250 mm with a 200 mm valve.

2. Low throughputs do not necessarily give lower purity molasses and better sugar, and they are not easier to control than high throughputs.

3. Centrifugals should be fed with massecuite of relatively constant viscosity and, what is most important, at a uniform flow rate. Very viscous massecuites can be diluted by the recycling of molasses (± 75° Bx. at 60°C) at the crystallizers.

4. Preconditioning of massecuite at the centrifugal should be carefully considered and facilities for coaxial and radial addition of water and steam should be provided. Steam and water washing sprays should be fitted in the basket as described.

5. The speed increase and perforations of the basket of No. 10 BMA at Darnall had less effect on performance than the modifications to the massecuite lubrication, to the sugar washing system and the fitting

Factory	Make	Massecuite Viscosity (Poise)	Massecuite/hr		Sugar Purity	Molasses Brix	Remarks
			kg	kg/m²			
DL	BMA K850	13 300 @ 55°C	921	1 218	84,6	85,9	Standard
,,	BMA K850	16 200 @ 54°C	2 332	3 085	85,2	78,7	Modified
,,	BMA K850	6 400 @ 54°C	2 766	3 659	80,2	79,1	Modified
,,	FC 1 000	1 300 @ 55°C	2 159	1 886	84,3	80,9	Standard
,,	FC 1 000	14 800 @ 58°C	3 198	2 793	84,1	79,0	Modified
,,	FC 1 000	7 800 @ 59°C	4 595	4 013	82,5	80,6	Modified 2 100 rpm
MV	Western States	10 000 @ 44°C	1 875	2 213	79,4	87,2	No steam
,,	Western States	2 500 @ 45°C	3 755	4 431	91,6	85,1	Steam
,,	Western States	2 700 @ 39°C	4 155	4 903	84,9	82,2	Steam
SZ	BMA K850	7 000 @ 59°C	2 390	3 161	83,0	77,7	Standard
,,	BMA K850	9 400 @ 58°C	1 760	2 328	82,8	79,2	Standard + lub. spray and steam

TABLE 3

	Fives Lille FC 1 000							BMA K850*			
Test	Capacity	Water		Molasses			Sugar	Molasses			Ave. Sugar
	Massecuite kg/h	% Massecuite	Lubrication % total	Brix	Purity	Diff. from Nutsch†	Purity	Brix	Purity	Diff. from Nutsch	Purity
A_1	2 324	7,7	83,3	81,3	38,3	2,3	86,1	81,6	37,9	1,9	84,9
	1 260	11,1	35,7	79,0	39,9	2,2	89,8	86,0	40,6	2,9	78,7
	3 225	8,0	76,9	80,3	39,5	1,8	81,3	84,6	40,5	2,8	77,1
	1 446	5,5	87,5	71,2	40,9	3,9	89,0	84,1	40,3	3,3	84,3
	2 770	5,1	85,7	74,0	39,6	2,6	84,3	84,4	40,6	3,6	78,6
A_1 Ave.	2 205	7,5	73,8	77,2	39,6	2,6	86,1	84,1	40,0	2,9	80,7
A_2	3 916	10,7	66,7	78,7	35,8	3,0	83,9	82,5	36,1	3,3	—
	4 736	10,6	61,8	78,5	34,7	1,9	78,2	83,2	34,9	2,1	—
	4 595	7,7	77,5	80,6	35,0	2,2	82,5	83,3	35,1	2,3	—
	3 497	12,3	82,6	77,6	35,3	2,1	84,3	80,9	36,1	2,9	—
A_2 Ave.	4 186	10,3	72,1	78,8	35,2	2,3	82,2	82,5	35,5	2,4	—
$A_1 + A_2$ Ave.	3,080				37,7	2,4			38,0	2,8	

* Standard BMA battery working under control of the factory operator.

† Mother liquor purity — Nutsch Purity.

TABLE 4

	Modified BMA K850 (No. 10)							Standard K850*		
	Capacity	Water		Molasses			Sugar	Molasses		Sugar
Test	Massecuite kg/h	% Massecuite	Lubrication % total	Brix	Purity	Diff. from Nutsch	Purity	Brix	Purity	Purity
B	2 100	5,5	51,7	81,6	37,9	1,9	79,9	81,6	37,9	84,9
	2 766	7,9	40,9	79,1	38,0	2,0	80,2	81,6	37,9	84,9
	1 130	3,7	100	82,8	39,9	2,2	80,6	86,0	40,6	78,7
	2 178	8,7	68,4	79,8	39,6	1,9	81,6	84,6	40,5	77,1
	967	3,5	100	84,8	39,3	—	83,1	84,1	40,3	84,3
	2 280	7,4	58,8	81,9	38,8	—	81,4	84,4	40,6	78,6
	1 904	6,1	70,0	81,7	38,9		81,1	83,7	39,6	81,4

* Standard BMA battery working under control of the factory operator.

of a larger iris valve. None of these modifications affected the scaling problem.

In order to obtain the maximum throughput and minimum downtime on a continuous centrifugal station it is recommended that:

(1) Solid basket centrifugals should be cleaned with chemicals at least once a week.

(2) The massecuite flowing into the reheater or centrifugal feed pipe should be screened to remove tramp iron which causes considerable damage to expensive screens.

(3) The centrifugal station should be provided with a stroboscope and the operator should be able to use it intelligently. Any uneven distribution of massecuite or screen damage could be corrected without delay and optimum performance re-established.

It would appear therefore that continuous centrifugals need a lot of attention and well-trained operators are essential. With the high capacity machines available, the number of units required will be less and this will reduce both initial and operating costs to the whole industry.

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