INCREASED CAPACITY OF CONTINUOUS CENTRIFUGALS ON LOW GRADE MASSECUITES

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Abstract

Modifications to BMA K850 centrifugals permitted increased throughputs of "C" massecuite in the order of 100%. The resultant molasses purities were little affected, but brixes were two degrees lower than before modification. Tests showed that the prototype BMA K1100 can handle four tons of "C" massecuite per hour with molasses purities comparable with those of standard centrifugals, but with brixes lower than normal. Techniques of process water application were examined.

Introduction

The paper has been divided into two parts. The first covers what will be termed "commercial" tests, which deal with the uprating of the BMA K850 and performance of the BMA K1100; the second covers experimental tests involving the addition of process water within the stream of massecuite.

In recent years a number of authors have shown that continuous centrifugals can handle higher "C" massecuite throughputs than was previously considered possible.

A throughput of 1,2 tons per hour (30 ft^3 per hour) of massecuite was established as a normal working load for a standard BMA K850 on fore-curing duty at Darnall in 1969.[3]

In 1973, also at Darnall,[1] de Robillard compared the performance of a standard K850 with a unit which had been modified in various respects (see table 2 explaining modifications). A capacity increase of 60%, representing a throughput of 1,9 tons per hour, was achieved. In that author's opinion, the feed modifications were the major contributions to this increase.

Atherton and Kirby[2] also mentioned in a review of their centrifugal research work, between 1963 and 1973, that restrictions in the massecuite feed piping had been to a considerable extent responsible for throughput limitations on continuous centrifugals.

The Huletts group has a large number of BMA K850's employed on C-massecuite and the possibility of uprating these machines is therefore of considerable interest. It was felt, however, that further attention should be given to two particular aspects of operation at high throughputs, before a final decision on uprating could be taken.

(1) The possible difference between centrifugal performance under experimental conditions and routine operation.
(2) The effect of higher throughput on molasses purity.

It was therefore decided that five of the ten fore-curers at Darnall should be modified and investigations be carried out to clear up the above points.

One of the disadvantages of experimental test runs is that the results indicate what the centrifugals can achieve under special supervision, and reflect data gathered over relatively short periods of time. The tests reported here covered periods of at least one week, with data recorded every four hours. The weekly averages should be less liable to distortion by random error than single-test data. As the centrifugals were entrusted to the mill operating staff, the results, it is hoped, will relate more closely to performance levels attainable during actual routine operation.

Laboratory methods of measuring brix and pol are not sufficiently accurate to detect fractional differences of purity between two determinations from single samples. The emphasis consequently has been on the average of a large number of apparent purity determinations rather than true purity results from single (or duplicate) analyses of composites. In fact, analyses of true purity duplicates have indicated that the between duplicates variance is not significantly less than that of apparent purity determinations.

The centrifugals

Specifications of the centrifugals are shown in Table 1, and features of particular interest of the standard BMA K850, modified K850 and BMA K1100 can be found in Tables 2 and 3.

TABLE 1
Specifications of the Centrifugals

Centrifugal / Measured Parameter	K1100	Standard K850	Modified K850
Basket cone half Angle with vertical	33°	35°	35°
Working screen aperture (mm) .	2 × 0,06	2 × 0,06	2 × 0,06
max. dia.	1 080	838	838
med. dia.	767	600	600
min. dia.	454	362	362
vertical height . . .	482	339	339
inclined length . . .	575	414	414
surface area M^2 . .	1,400	0,781	0,781
Basket speed RPM (nominal) . .	1 947	2 158	2 220
GA factor* at med. screen dia.— m^2(x10^{-3})	2,28	1,22	1,29

* Gravity factor multiplied by screen area in square metres.

TABLE 2
Features of the BMA K850

Unmodified K850	Modified K850
100 mm dia. Stafsjo valve in massecuite feed.	Stafsjo valve removed.
100 mm dia. iris valve in massecuite feed.	150 mm unit replaces the 100 mm valve.
Process water applied only at feed cone.	Process water applied through a lubrication rod co-axial with the massecuite feed. See Figure 1.
Basket speed 2 158 rpm	Basket speed 2 220 rpm.*
Motor pulley 280 mm diameter	Motor pulley 288 mm diameter.
Basket pulley 190 mm diameter	Basket pulley 190 mm diameter.
No holes in the basket.	Three rows of 24 holes in grooves drilled in basket in order to improve molasses drainage. See Figure 3 for layout.

* It was intended to increase basket speed to 2 350 rpm. This requires a 300 mm motor pulley. Through a misunderstanding, a 288 mm pulley was used instead.

TABLE 3
Features of the BMA K1100

1. Drilled basket to assist molasses drainage: Three rows of holes 6,5 mm diameter in grooves of 10 mm, within 200 mm of the bottom of the basket.
2. Drilled clamping ring at the bottom of the basket to assist molasses drainage. (These holes were covered throughout the tests.)
3. The acceleration cone, fabricated in stainless steel is of the kind found in the advanced type S BMA K850. The vertical height is greater than that of the standard K850 cone and the mixing cup is deeper. Pins are provided in the mixing cup to assist mingling.
4. Massecuite is fed through a 200 mm diameter iris valve.
5. A cylindrical perspex windage shield was fitted between the massecuite feed valve and the feed cone for some of the tests.
6. Process water was applied by means of a lubrication rod co-axial with the massecuite feed at the iris valve, in addition to the normal feed cone spray found on the K850 machine.

Terms used for centrifugal components are indicated in Figure 2, and details of basket modifications appear in Figure 3.

Part 1 — The commercial tests

Procedure

Following on from the experimental work on one modified BMA K850, the "commercial" tests were a simulation of normal operating conditions at the mill, but at high throughputs.

It was found experimentally that, on a continuous centrifugal with increasing massecuite throughput, the amount of process water required to maintain a sugar purity of 80° increased in greater proportion, i.e. the water % massecuite increased. Increasing the throughput, a point was reached where the emergent sugar was wet and of low purity. Apparently mingling of water and massecuite was so inefficient at this stage that curing became unsatisfactory, with water running up the basket on the massecuite surface. Throughout the commercial runs it was endeavoured to keep throughput as high as possible without reaching this condition. Sugar purity was maintained at 80°, the plant average.

Throughput was estimated by measuring molasses flow rates and calculating massecuite throughputs via pol balances.

Massecuite was sampled every four hours and analysed for brix and purity. Mother liquor purities were obtained using a nutsch "bomb" at 50° C and 320 kPa with a 0,09 × 2 mm screen.

The molasses from each centrifugal under test was sampled every half an hour and composited for four hours. These composites were divided into two portions; one portion analysed by Darnall laboratory for brix and pol; the other collected to provide a weekly composite for analysis by Huletts Research and Development.

The following commercial tests were carried out:

(1) A two week high capacity test (1a) with the five modified K850's handling the total production, followed by a control week at low capacities (1b) on both standard and modified centrifugals. The object of this test was to ascertain whether five modified centrifugals were capable of handling the total production of C-massecuite. As mixed juice purities decreased markedly, it became necessary to modify another K850 centrifugal to cope with increased massecuite volume. This centrifugal was not used for the total duration of the test, but only at peak load times.

(2) A one week test with the modified K850's at high capacity and the standard K850's at normal capacity, both treating the *same* massecuite.

(3) A one week run of the BMA K1100.

(4) A one week test of the standard K850, modified K850 and the K1100.

Analyses of variance were carried out on the molasses purities and on the nutsch purity rise data from tests 2 and 4. Simple additive models employing a constant term, a time effect and an effect for centrifugal type, were used. The residual error variances due to sampling, analyses and undetermined sources were computed for tests 2 and 3, and pooled.

A 95% confidence interval was constructed for "d", the mean value of the molasses purity of the modified K850 minus that of the standard K850, employing the pooled residual variance in the estimate of the standard error of "d" (see Appendix I).

Results and discussion of commercial tests

K850 Results

Table 4 shows the results of the tests on the K850.

It can be seen that the modified K850 handled approximately twice the massecuite throughput of the unmodified K850. The throughput limitation discussed under *Procedure* is

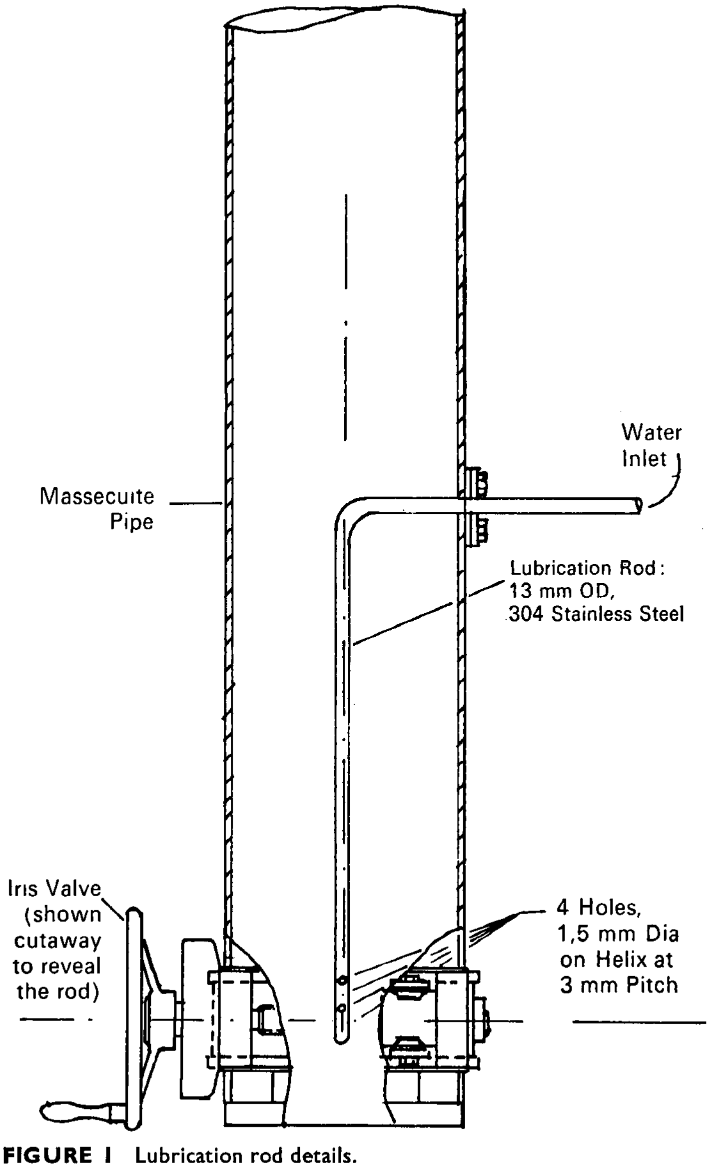

FIGURE 1 Lubrication rod details.

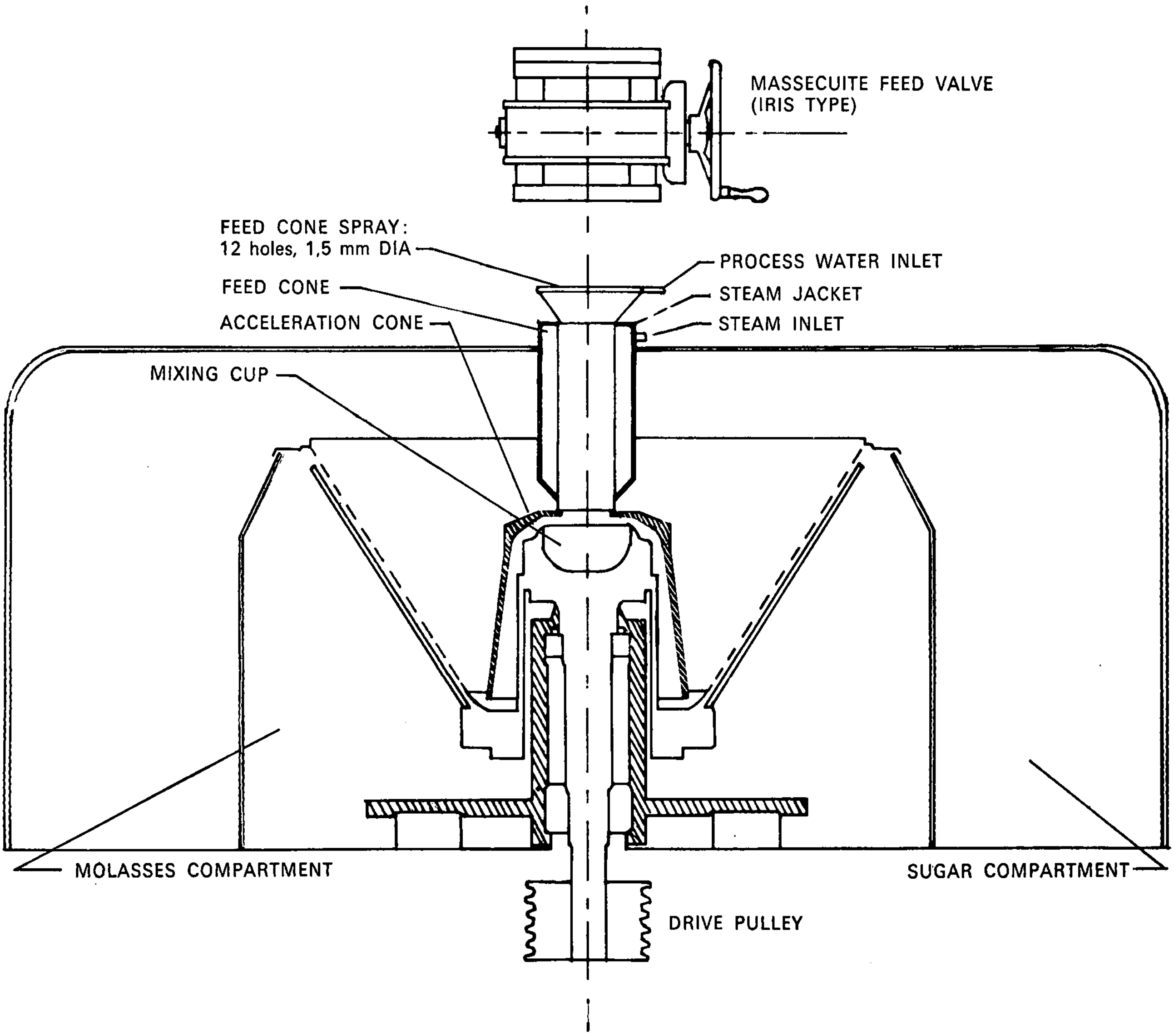

FIGURE 2 Terms used for centrifugal components.

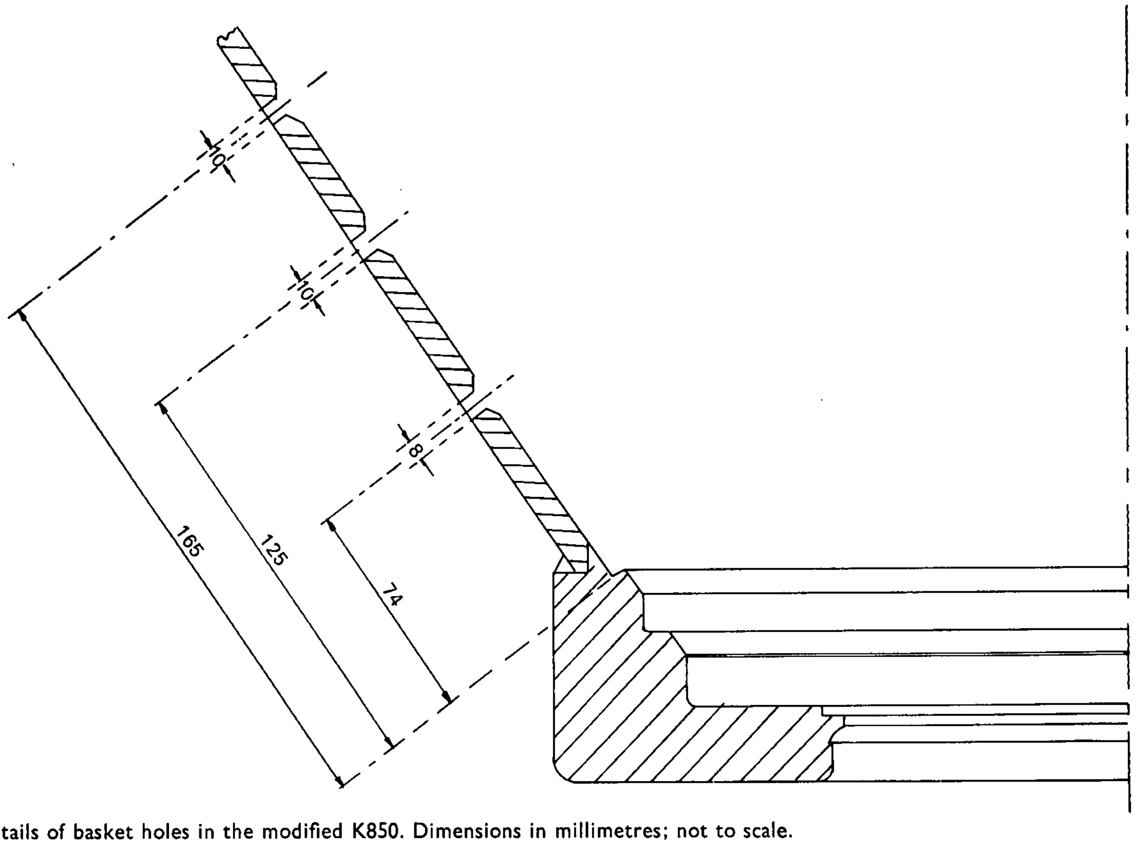

FIGURE 3 Details of basket holes in the modified K850. Dimensions in millimetres; not to scale.

TABLE 4

Results of the Commercial Tests

Massecuite consistency ranged from 500 to 800 Pa: s, with a flow behaviour index of 0,75-0,8 at 58° C, the temperature of curing.

Test	Centrifugal	Massecuite Throughput		Sugar Purity	Apparent Purity Molasses		Nutch Purity Rise	Refracto Brix	Total* Solids	Target* Purity Difference	Massecuite Properties	
		ft³/h	t/h			*					Brix	Purity
1 (*b*)	K850	30	1,2	81,3	30,9		2,8	87,0	83,7	1,2	98,9	53,0
1 (*a*)	mod. K850	55	2,2	81,4	30,4		2,2	85,0	81,3	1,2	98,8	53,0
2	K850	32	1,2	81,1	32,0		2,5	87,5	84,1	1,2	96,7	54,1
	mod. K850	65	2,6	81,6	32,0		2,5	85,5	81,9	1,2		
3	K1100	93	3,7	81,0	29,7	30,5	1,7	86,8	81,1	3,7	97,4	53,1
	All machines	26	1,0	80,4	30,1	31,2	1,9	88,7	83,4	4,0		
4	K850	25	1,0	81,8	30,6	31,4	2,6	90,9	84,9	2,3	96,8	53,7
	mod. K850	51	2,0	82,3	30,9	—	2,8	88,2	82,4	2,2		
	K1100	113	4,5	82,3	30,5	32,2	2,5	85,7	80,7	2,3		
	All machines	63	2,5	82,2	30,6	31,8	2,6	87,1	81,4	2,1		

* Determinations by Research and Development on weekly composites.

of significance, in that throughput could possibly be increased if better mixing of water and massecuite were achieved. It should be noted that the centrifugals tested did not have pins or other aids in the mixing cups.

The brix of the molasses from the modified K850 was between two and three degrees lower than that from the standard K850. This was to be expected, since the water to massecuite ratio was approximately 7% on the modified K850, but only 3% on the standard K850 ... another manifestation of poorer water-massecuite mixing at high throughputs.

The accuracy of the throughput measurement was limited by the method of weighing the molasses, but should be within ± 10% of the true value.

Losses of process water through evaporation were neglected in the throughput determinations. A loss of 20% of process water would result in an estimated throughput approximately 2% lower than the true value, when the water to massecuite ratio is 10%.

The consistency of the massecuite ranged between 500 and 800 Pa's (5 000-8 000 poise), with a flow behaviour index of 0,75 at 59° C, the average temperature of curing. Since massecuite is a non Newtonian material, viscosity, as measured for example on a Brookfield viscometer, will vary with the shear rate imposed on the massecuite during the determination. A massecuite will therefore apparently have a different viscosity at two different viscometer spindle speeds. The consistency is independent (or nearly so) of spindle speed and should be a more meaningful measure of massecuite fluidity.

The molasses purities from the standard and modified K850 centrifugals were very similar. The purities quoted from test (1) are not comparative "inter se", because the high and low capacity tests were not simultaneous.

The combined result of tests (2) and (4) show, however, that the average purity (69 determinations) of the molasses from the modified K850 was 0,1 units higher than that from the standard K850. The 95% confidence interval for "d" (modified K850 molasses purity minus standard K850 molasses purity) is as follows:

$$-0,2 \leq d \leq 0,3 \qquad \ldots \text{ (K850 centrifugal)}$$

Using the analysis presented, all values of "d" within the interval are not contradicted by the data.

There is not enough evidence to indicate whether or not "d" converges to a particular value over a season or longer. The Rand value of 0,1 units of exhaust molasses purity over a few seasons is appreciable, and therefore further data collection would appear to be worthwhile.

The increased throughput has not caused problems with mechanical maintenance. Screen life has not been affected and mixing cup wear, although not actually measured, was not apparent.

*K*1100 *Results*

Table 4 also shows the results of the K1100 commercial tests. The massecuite throughput of approximately 4 tons per hour should be related to the massecuite properties in the table.

The process water required to maintain 80° purity sugar ranged around eight per cent by weight on massecuite, and molasses brix was 4,7 degrees lower, on average, than that of the standard K850.

This aspect of the performance (higher water percent massecuite and lower molasses brix) was also characteristic of the modified K850. A prototype feed cone, designed to improve mixing of water and massecuite, awaits testing during the 1975/76 crushing season.

The quantity "d" for the K1100 (i.e. K1100 molasses purity minus standard K850 molasses purity) averaged — 0,1 (test 4). The 95% confidence interval was as follows:

$$-0,5 \leq d \leq 0,3 \qquad \ldots \text{ (K1100 centrifugal)}$$

All values of "d" within the interval are not contradicted by the data, which include 24 four-hourly determinations. The remarks on "d" converging over a crushing season also apply to the K1100.

The screens on the K1100 have not required more frequent cleaning than those of the K850 and have lasted for three months of continuous operation, which is the life of a K850 screen at Darnall. The deep mixing cup of the K1100 required regular washing, whilst other mechanical aspects are beyond the scope of this paper.

Part 2 — Method of water application

The purpose of this experiment was to compare the "lubrication rod" and feed cone methods of applying process water to the modified K850 centrifugal.

Two modified machines were set up under similar conditions. Both treated the same massecuite, the feed valves opened to the same extent and water feed rates were equal. One centrifugal was run with process water applied through a lubrication rod (as in Figure 1), the other by means of the normal feed cone. A time of twenty minutes was allowed for conditions to reach a steady state. Three responses, sugar purity, molasses purity and molasses brix were measured from each machine. The water feed configurations were alternated twelve times between centrifugals at throughputs in the region of 2,4 tons per hour, which is close to the maximum for a modified K850. An analysis of variance was carried out for each response as for the commercial runs, but including a treatment effect (lubrication rod or feed cone), in the associated model.

TABLE 5

Comparison between methods of water application to the modified BMA K850

	Sugar Purity	Molasses Purity	Molasses Brix
Lubrication rod* . . .	80,8	31,2	85,8
Feed cone*	78,7	31,0	85,4
Difference	2,1	0,2	0,4
Statistical significance at 95% confidence level .	significant	not significant	not significant

* Averages of 12 determinations.

The two treatment averages for each response were compared and differences evaluated in the light of the residual errors (as outlined in Appendix 1).

Results and discussions

The results of the experiment to compare methods of water application to the modified K850 are shown in Table 5. Use of the lubrication rod instead of the feed cone for the same massecuite and water flow rates improved sugar purity by an average of 2,1 units. This is significant at the 99% level of confidence, and as such the inference of improved sugar purity should be valid for the conditions of the tests.

The 0,4 difference between the brixes, although not significant, could have been caused by a slight increase in throughput resulting from reduced resistance to the feed from the lubrication rod, when the latter was wet.

The co-efficient of variation between duplicate molasses purity analyses was found to be about 3%, and this error alone could account for the 0,2 difference between the molasses purities.

The results obtained are in agreement with earlier work carried out at Darnall in July 1974.

The experiment was also attempted at low throughputs of the order of one ton/hour, but the results were not clear. This was possibly due to interference with the massecuite flow by the lubrication rod when running dry.

Conclusions

(1) Modifications to the BMA K850, as described, gave rise to the following performance changes:
   (*a*) Massecuite throughput on fore-curing of C-massecuites was increased by between 80 and 100%, i.e. from 1-1,5 tons per hour to 2-3 tons per hour, for the same C1 sugar purity (80°).
   (*b*) The apparent purity of the molasses, averaged over 69 determinations, was 0,1 units higher than that of the standard K850, when treating the same massecuite. The 95% confidence level for "d" (apparent purity of molasses from the modified K850 minus that from the standard K850) were as follows:

$$-0{,}2 \leq d \leq 0{,}3$$

   (*c*) Molasses brix was between two and three degrees lower than that of the standard K850 due to an increased process water requirement.

(2) Screen life was unaffected by the modifications.

(3) Application of process water through a rod co-axial to the massecuite flow, instead of through the feed cone, resulted in more effective curing at elevated throughputs.

BMA K1100

The performance of the BMA K1100 on fore-curing duty of C-massecuites maintaining a C1 sugar purity of 80° is as follows:

(1) The centrifugal is capable of handling 4 tons per hour, but on occasions has reached 6 tons per hour.

(2) The apparent purity of molasses, averaged over 24 determinations, was 0,1 units lower than that of the standard K850, when treating the same massecuite from a common feed. The 95% confidence limits for D (apparent purity of molasses from the K1100 minus that of the molasses from the standard K850, treating the same feed) were as follows:

$$-0{,}5 \leq D \leq 0{,}3$$

(3) Molasses brix, at throughputs of approximately 4 tons per hour, was between four and five degrees lower than that of the standard K850.

Screen life has been equal to that of the standard K850 centrifugals.

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Appendix I

Statistical computations employed

(*a*) *Commercial Tests*

It was assumed that each molasses purity observation was constituted as follows:

$$Pij = Y + Ti + Cj + Eij$$

where Pij = Molasses purity determined at time i from centrifugal j

Y = Overall average molasses purity

Ti = Effect on purity due to time i (e.g. slack massecuite)

Cj = Effect on purity due to the particular centrifugal type (standard K850, modified K850, K1100)

Eij = Residuals, not assignable to time or centrifugal; including sampling and analysis errors; Mean assumed zero; variance assumed equal to σ^2 the variance of the molasses purities.

The sum of the square of the differences between the Pij and Y $\Sigma(Pij - Y)^2$ was considered to be composed of sums of squares due to each of the effects above and a residual sum of squares. The mean residual sum of squares was obtained by calculating the sums of squares due to times and centrifugals and subtracting these from $\Sigma\ (Pij - Y)^2$ and obtaining a mean value, s^2.

This estimate σ^2 above, where σ is the standard deviation of the molasses purities without interference from time or centrifugal effects.

If measurements are randomly scattered about a mean value m, they tend to be "normally" distributed, with 95% of them falling in the interval $m \pm 1{,}96\sigma$, where, as above, σ is the standard deviation. If therefore, σ is known and a measurement y is observed, the probability is 0,95 that the interval $y \pm 1{,}96\ \sigma$ will capture the true value of the parameter being measured. For averages, $\bar{y}$, of N observations, the probability is 0,95 that the interval $\bar{y} \pm 1{,}96\sqrt{\sigma^2/N}$ will capture the true value of the mean. This interval is a 95% confidence interval.

Where, as in the case with the molasses purities, σ^2 is not actually known, but only estimated by s^2, the 95% confidence interval is $\bar{y} \pm t\sqrt{s^2/N}$. The "t" is the Student's tee statistic and is available in tables. It compensates for the fact that σ^2 was merely estimated. In the case of the molasses purities, $\bar{y}$ above is actually $\bar{d}$, a difference between *two* averages. The interval must accordingly take this into account and is $(\bar{y}_2 - \bar{y}_1) \pm t\sqrt{2s^2/N}$.

(*b*) *Experiment to compare methods of application of Process water*

The analysis of this experiment was very similar to that outlined above.

A model of the constituents of each observation was employed, similar to that for the molasses purities above, but including W_r, an effect due to type of water application ... lubrication rod or feed cone.

In the calculation to estimate s^2, sums of squares due to water application effect were subtracted from $\Sigma\ (Pij - Y)^2$ in addition to those associated with the other effects.

Again, $(\bar{y}_2 - \bar{y}_1) + t\sqrt{2s^2/N}$, was evaluated where, this time $(\bar{y}_2 - \bar{y}_1)$ was the difference between the average measurement with rod application and the average with feed cone application.

The test for statistical significance amounted to examining the interval above to see if it included zero. Since the probability is 0,95 that this interval contains the true value of $(\bar{y}_2 - \bar{y}_1)$ it is unlikely that the real $(\bar{y}_2 - \bar{y}_1)$ will fall outside it. If the interval does not include zero, therefore, the assumption that the true value of $(\bar{y}_2 - \bar{y}_1)$ equals zero, makes the observed $(\bar{y}_2 - \bar{y}_1)$ a rare event. This is unacceptable. Instead, the difference $(\bar{y}_2 - \bar{y}_1)$ is taken as real or "statistically significant" and the assumption that $(\bar{y}_2 - \bar{y}_1)$ equals zero is rejected.

Appendix II

Determination of massecuite flow rate

Massecuite flow rate was determined by pol balance from molasses flow rate, corrected for added process water.

The following formulae were used:

$$M = (L - W)\frac{(Ps - Pc)}{(Ps - Pm)}$$

$$Pc = \frac{Pr}{1 - \frac{W}{L}}$$

where M = Massecuite flow rate kg/h

L = Molasses (runoff) flow rate kg/h

W = Water flow rate kg/h

Ps = Pol of the sugar

Pc = Corrected pol of the molasses

Pr = Measured pol of the molasses

Pm = Pol of the massecuite.

Pr, the measured pol of the molasses, is corrected in the formula above to Pc, to allow for the effect of molasses dilution by process water.