THE EFFECT OF LOW JUICE PURITIES AT DARNALL ON BOILING HOUSE CAPACITY

by R. D. ARCHIBALD
Huletts Sugar Limited, Darnall
and I. A. SMITH
Huletts Sugar Limited, Technical Management Department

Abstract

Drought conditions raised non-pol content of cane delivered to Darnall mill during the 1974/75 season to almost 50% above average values at times. Crushing rate was nevertheless maintained at a high level and the background to attainment of greatly increased factory throughputs is reported. Estimations of maximum pan station capacity agree well with actual rates. Major factors contributing to the higher throughputs were good flexibility of pans between the different massecuite grade duties, absence of unfavourable massecuite boiling characteristics, a number of changes carried out to minimise pan operation time, and the ability of the continuous C-centrifugal station to handle rates well in excess of design capacity.

Introduction

As a result of severe drought conditions, the non-pol content of cane supplied to Darnall mill during the 1974/75 season rose to record levels. The excessive loading on the factory back end resulting from such cane quality can normally be expected to restrict cane throughput. However this did not happen and the mill in fact showed a substantial improvement in crushing rate over previous-best levels instead of a reduction.

The ability to maintain a high crushing rate was of considerable benefit in the prevailing circumstances of abundant can availability. All three of the Huletts Zululand mills, which had similar cane quality patterns, were forced to reduce throughput to a greater or lesser extent. It was therefore felt worthwhile to examine in some detail the situation at Darnall to establish how a similar reduction had been avoided there.

Juice purities as low as those experienced at Darnall last season do not occur very often. When they do, it is usually at the end of the season when both cane supply rates and brix % cane have fallen off, so that there is little pressure on the boiling house. The effect of low input purities on maximum boiling house capacity therefore tends to be rather an unfamiliar area. To throw some light on this matter, boiling house brix balances were drawn up for the standard Partial Remelt System at different syrup purities. Further calculations were done on the results of this exercise to arrive at estimates of maximum pan station capacity at the various input purity levels.

Comparison of actual throughputs with calculated maxima showed generally good agreement. Plant and process changes which enabled the theoretical limit to be exceeded slightly on occasions were listed. Factors which can, and often do, prevent the estimated maximum throughputs from being attained were isolated.

The question of the effect of input purity level on boiling house capacity is an important one at the present time when growing cane supplies are placing an increasing load on mills throughout the industry. The work described above was therefore collated and is presented here.

Rainfall pattern at Darnall in 1974

Monthly rainfall at Darnall in 1974 is shown in Figure 1 together with the means for the 41 years from 1933 to 1973. Although rainfall for the year was 75% of the long-term average, the total of 55 mm for the five months June to October 1974 was only 20% of the 41-year mean for the corresponding period. Past records have not been examined in any detail but there cannot have been many dry spells that have equalled in length and severity the one experienced in 1974.

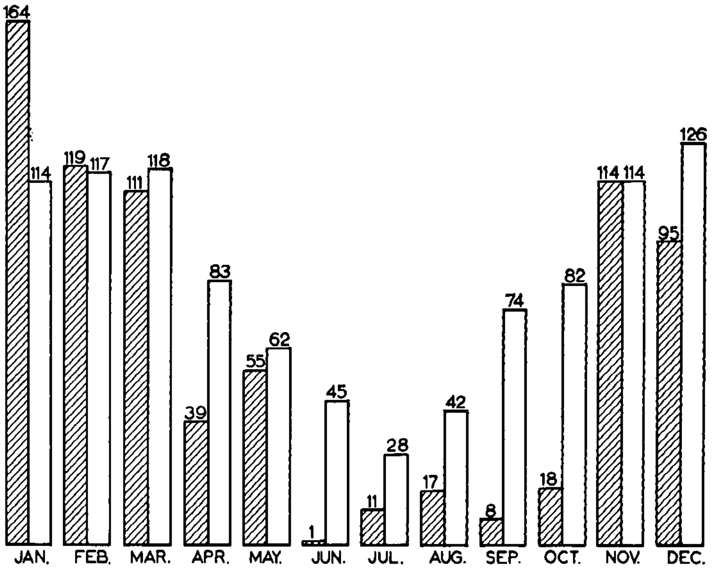


FIGURE 1 Monthly rainfall at Darnall mill. Shaded columns — 1974. Unshaded columns — 41-year mean. Figures above columns — rainfall in mm.

Evaluation of 1974/75 juice impurity levels

(1) *Comparison between cane supply areas*

The 1974 winter drought affected the cane crop throughout the entire South African industry. The abnormally high impurity contents which characterise severely drought-affected cane were however mainly confined to the coastal belt from Stanger to beyond Empangeni. This comprises the bulk of the cane supply area for each of the four northern Huletts mills. Values for three cane quality parameters were calculated for these four mills as a whole, and for the remainder of the industry. Resultant plots of mixed juice purity, brix in mixed juice % cane and non-pol in mixed juice % cane appear in Figure 2. The pattern for the Huletts mills of good juice purities early in the season followed by a catastrophic drop as from September, is not repeated for the rest of the industry. In addition the higher mid-season brix content of cane for the affected area, as reflected in the second plot, combined with the low purities to give an exceptionally high non-pol level. The graphs of non-pol in mixed juice % cane show a value

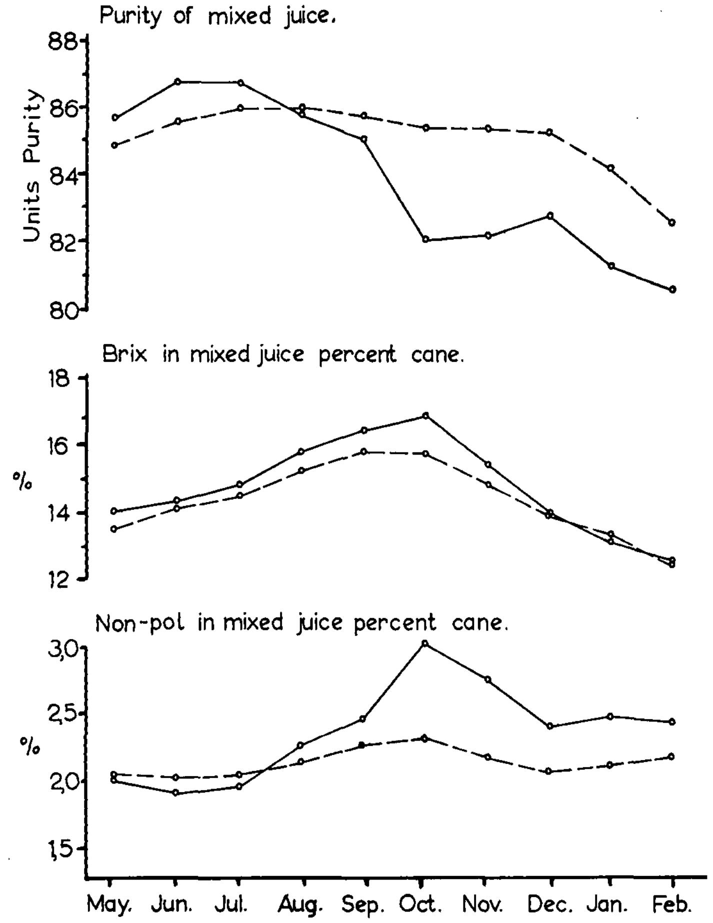


FIGURE 2 Comparison of 1974/75 cane quality at Huletts northern mills (————) and rest of industry (– – – – – –).

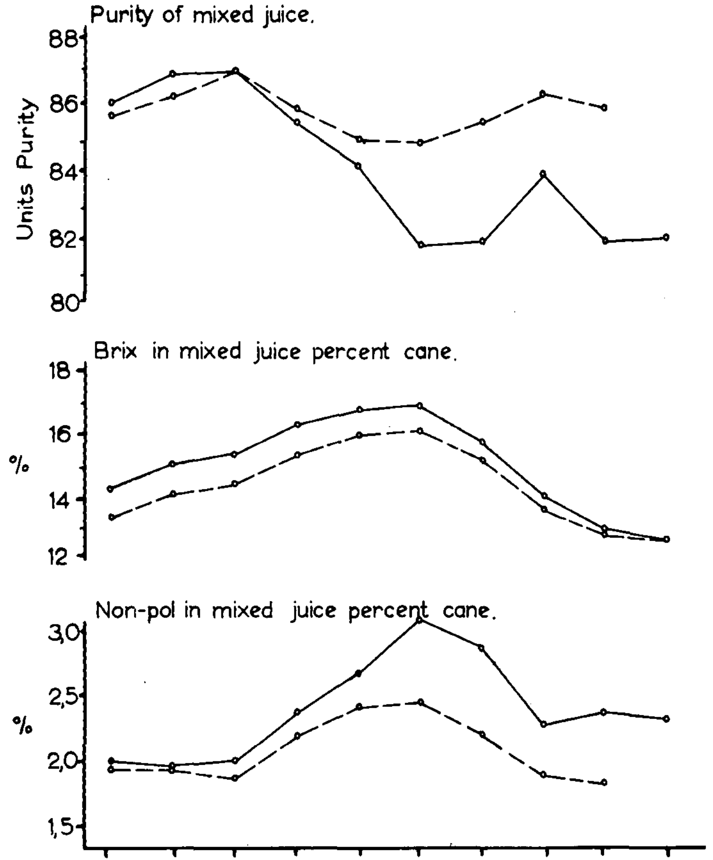


FIGURE 3 Comparison of 1974/75 cane quality at Darnall (————) and and Gledhow (– – –).

for the Huletts mills in the peak month of October that is 30% higher than the corresponding figure for the rest of the industry.

The degree of localisation of the high-impurity cane is further illustrated in Figure 3. Here the cane quality comparison is between Darnall and the neighbouring mill of Gledhow. Despite the adjacent cane supply areas, the mid-season trough in juice purity and peak in non-pol content were far less pronounced at Gledhow than at Darnall.

(2) *Comparison with previous lowest purity season*

In addition to the above assessment of purities in the 1974/75 season, it would be of interest to compare the Darnall figures with those for previous seasons at the same mill. A major difficulty arises here. In 1972 the analytical methods specified for mixed juice were changed. Direct polarisation replaced analysis for sucrose by double polarisation, and precision refractometers were introduced for brix determination in place of spindles. The new brix method gives lower figures due largely to elimination of the artificial inflation by suspended solids that influenced the spindle results. In consequence the assessment of impurity level is now considerably lower than that formerly given by the use of spindles. Any exercise that compares current purity figures with pre-1972 values without taking this difference into account is therefore likely to lead to erroneous conclusions.

A quantitative estimate of the difference in juice purity between the two sets of analytical methods has been made and is reported in Appendix 1. An average difference slightly in excess of two units of purity is indicated by the results of this exercise. MacGillivray and Graham[1] report a difference of 1,2 units on mixed juice by direct comparison but express reservations about the accuracy of this figure due to small number of data sets and high standard deviation. The average difference found for first expressed juice in a more comprehensive comparison was 3,4 units, or if a number of excessively large differences due to abnormally high suspended solids are excluded, 2,5 units.

It is therefore considered that the addition of 2,0 units to sucrose/spindle mixed juice purities is a reasonable correction to bring such values into line with pol/refractometer figures.

Examination of spindle mixed juice purities for Darnall since 1926 showed that the lowest season-average value occurred in 1962/63. This season was characterised by drought, fires and a large proportion of old carryover cane[4]. Apart from the last feature conditions were therefore similar to 1974/75 and the same combination of high pol contents and low purities occurred. Monthly average data was extracted, mixed juice purities adjusted upwards by two units, and brix and non-pol in mixed juice % cane values calculated. The resultant figures are plotted in Figure 4 together with the corresponding 1974/75 results.

Although season-average purities were similar for the two seasons, the 1974/75 monthly plot shows a much greater drop from a high-purity period in the first three months to a low point one unit below the 1962/63 minimum. The other graphs also show higher maxima for last season's cane. Brix in mixed juice % cane was only slightly over the 1962/63 peak but the difference for non-pol is much greater with a maximum for last season that was 48% above long-term mean as opposed to only 27% for 1962/63.

The 1962/63 season was categorised as the worst yet as far as juice purities were concerned.[4] It appears that, in the case of Darnall at least, the record books must now be rewritten.

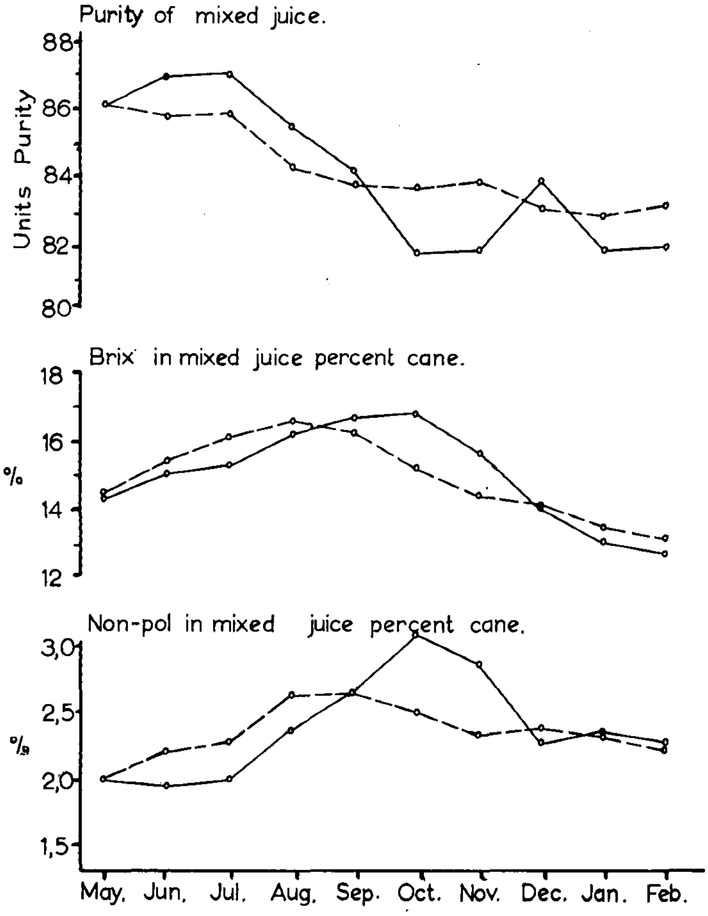


FIGURE 4 Comparison of cane quality at Darnall in 1974/75 (———) and 1962/63 (– – –).

Estimation of maximum pan station capacity at various input purity levels

Boiling house brix balances have been drawn up for four syrup purity levels — high (89,5), average (87), low (83) and very low (81). Respective intermediate purity levels typical for Darnall were used in the calculations. Details of the assumptions made are noted in Appendix 2 and the resultant brix balance data appears in Figure 5.

From the ratios of solids in massecuite to solids in syrup given by the brix balances, massecuite volumes per unit of brix in mixed juice were calculated. By introducing values reflecting boiling time requirements for the different massecuite grades, estimates have been made of maximum boiling house input rates and corresponding massecuite volume rates. Calculation procedures are explained in Appendix 3 and the data is listed in Table 1.

For this type of exercise it is necessary to make a number of assumptions at various stages and the values finally derived may therefore not be entirely correct in absolute terms. The figures should however reflect accurately the *relative* changes for the different purity levels. The percentage changes in mass input and massecuite volume rates from those at average purity (87) are therefore shown in Table 2. These figures will moreover be generally applicable as opposed to the absolute values in Table 1 which refer to Darnall's throughput level only.

Two major assumptions implicit in the calculations leading to the above figures should be mentioned here:

(i) Sufficient flexibility on the pan floor to permit the required change of pans between duties.

(ii) No influence of input purity on average boiling times.

It should also be remembered that this data applies to the pan floor only and takes no account of possible limitations in other departments such as centrifugals.

It has been questioned whether retention of the Partia Remelt System is appropriate at very low purities. A brix balance was therefore drawn up for a two-boiling system at 81 syrup purity as it would be applied in the Darnall situation. The resultant estimated maximum pan station capacity is 5% higher than the figure for the Partial Remelt System at the same syrup purity, provided that boiling times remain unchanged. A lower C-boiling time might be expected due to higher C-massecuite purity, but on the other hand a longer boiling time for A-massecuites could be necessary with the smaller C-magma grain size. A considerable increase in loss of sucrose in molasses would inevitably result due firstly to

TABLE 1

(a) Derivation of maximum factory loading estimates from brix balance data

	Syrup purity	Massecuite A	Massecuite B	Massecuite C
Ratio massecuite solids to syrup solids (R)	89,5	1,372	0,487	0,294
	87	1,341	0,461	0,342
	83	1,280	0,414	0,425
	81	1,274	0,400	0,506
Solids % massecuite (S)		92	94	96
Massecuite density (D)		1,44	1,46	1,48
m³ massecuite per ton brix in mixed juice $\left(V = \frac{98,35R}{SD}\right)$	89,5	1,019	0,349	0,204
	87	0,996	0,330	0,237
	83	0,950	0,297	0,294
	81	0,946	0,287	0,350
Pan Time Index (t)		4,5	6,0	9,0
Pan capacity distribution m³ (C) (for derivation see Appendix 3)	89,5	168	77	67
	87	162	72	77
	83	153	64	95
	81	145	59	107
m³/hour massecuite $\left(\frac{C}{t}\right)$	89,5	37,3	12,8	7,5
	87	36,1	12,0	8,6
	83	34,0	10,6	10,5
	81	32,3	9,8	11,9

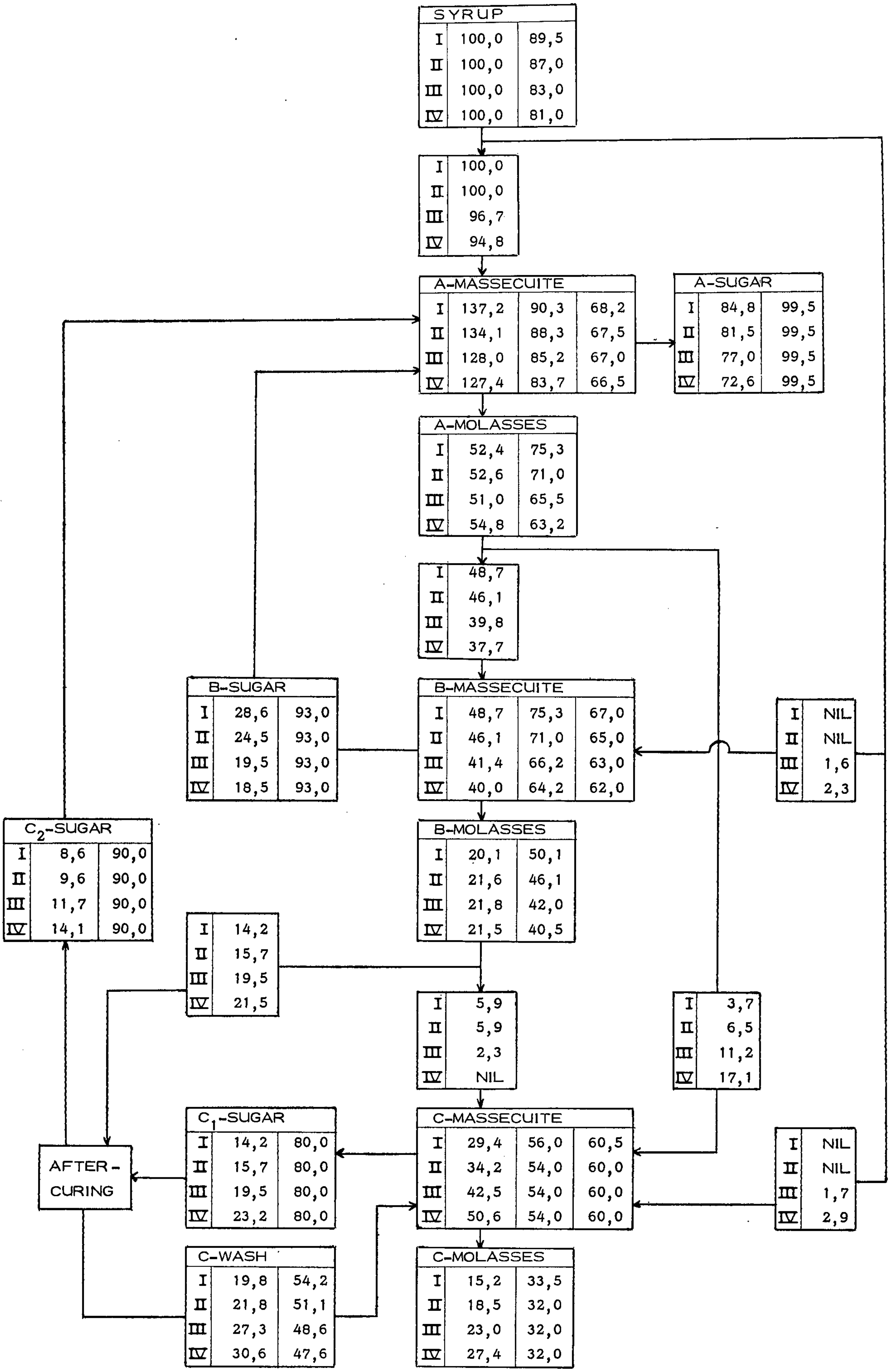
(b) Maximum factory input rates

Syrup Purity (J)	89,5	87	83	81
Tons Brix in mixed juice per hour $\left(B = \frac{C}{tV}\right)$	36,6	36,2	35,8	34,1
Tons Non-pol in mixed juice/hour $\left(N = \frac{100 - (J + 1)}{100}B\right)$	4,2	5,1	6,4	6,8

TABLE 2

Percentage changes in maximum factory input and massecuite volume rates

Syrup purity	Tons brix in mixed juice per hour	Tons non-pol in mixed juice per hour	m³ massecuite per hour A	m³ massecuite per hour B	m³ massecuite per hour C
89,5	+1	−18	+3	+7	−13
87	—	—	—	—	—
83	−1	+26	−6	−9	+22
81	−6	+33	−9	−18	+38



SYRUP		
I	100,0	89,5
II	100,0	87,0
III	100,0	83,0
IV	100,0	81,0

I	100,0
II	100,0
III	96,7
IV	94,8

A-MASSECUITE			
I	137,2	90,3	68,2
II	134,1	88,3	67,5
III	128,0	85,2	67,0
IV	127,4	83,7	66,5

A-SUGAR		
I	84,8	99,5
II	81,5	99,5
III	77,0	99,5
IV	72,6	99,5

A-MOLASSES		
I	52,4	75,3
II	52,6	71,0
III	51,0	65,5
IV	54,8	63,2

I	48,7
II	46,1
III	39,8
IV	37,7

B-SUGAR		
I	28,6	93,0
II	24,5	93,0
III	19,5	93,0
IV	18,5	93,0

B-MASSECUITE			
I	48,7	75,3	67,0
II	46,1	71,0	65,0
III	41,4	66,2	63,0
IV	40,0	64,2	62,0

I	NIL
II	NIL
III	1,6
IV	2,3

C$_2$-SUGAR		
I	8,6	90,0
II	9,6	90,0
III	11,7	90,0
IV	14,1	90,0

B-MOLASSES		
I	20,1	50,1
II	21,6	46,1
III	21,8	42,0
IV	21,5	40,5

I	14,2
II	15,7
III	19,5
IV	21,5

I	5,9
II	5,9
III	2,3
IV	NIL

I	3,7
II	6,5
III	11,2
IV	17,1

C$_1$-SUGAR		
I	14,2	80,0
II	15,7	80,0
III	19,5	80,0
IV	23,2	80,0

AFTER-CURING

C-MASSECUITE			
I	29,4	56,0	60,5
II	34,2	54,0	60,0
III	42,5	54,0	60,0
IV	50,6	54,0	60,0

I	NIL
II	NIL
III	1,7
IV	2,9

C-WASH		
I	19,8	54,2
II	21,8	51,1
III	27,3	48,6
IV	30,6	47,6

C-MOLASSES		
I	15,2	33,5
II	18,5	32,0
III	23,0	32,0
IV	27,4	32,0

FIGURE 5 Boiling House brix balances at Darnall for different input purity levels.
Block legend: First column — Units brix. Second column — Pol purity. Third column — Massecuite exhaustion.

higher C-massecuite purity (60 plus instead of 54) and secondly to the need to use the B-massecuite line for C. The shorter massecuite retention time and absence of cooling/reheating facilities would result in a still higher molasses purity for the portion of the total C-massecuite flow handled through this line.

If adverse massecuite boiling characteristics were to enforce a rise in C-massecuite purity, then a two-boiling system might be a proposition. Where low-purity C-massecuites can still be successfully boiled, as was the case at Darnall last season, it can however be concluded that abandonment of the Partial Remelt System for which the plant is set up, is not warranted.

Actual operating results

Figure 6 shows plots of monthly average tons brix in mixed juice per hour and tons non-pol in mixed juice per hour for 1974/75 and for the respective previous highest-rate seasons, 1972/73 and 1967/68. Note that these former maxima occurred in different seasons, brix rate in 1967/68 being well below 1972/73 level and vice versa for non-pol. Last season's records on the other hand were achieved simultaneously.

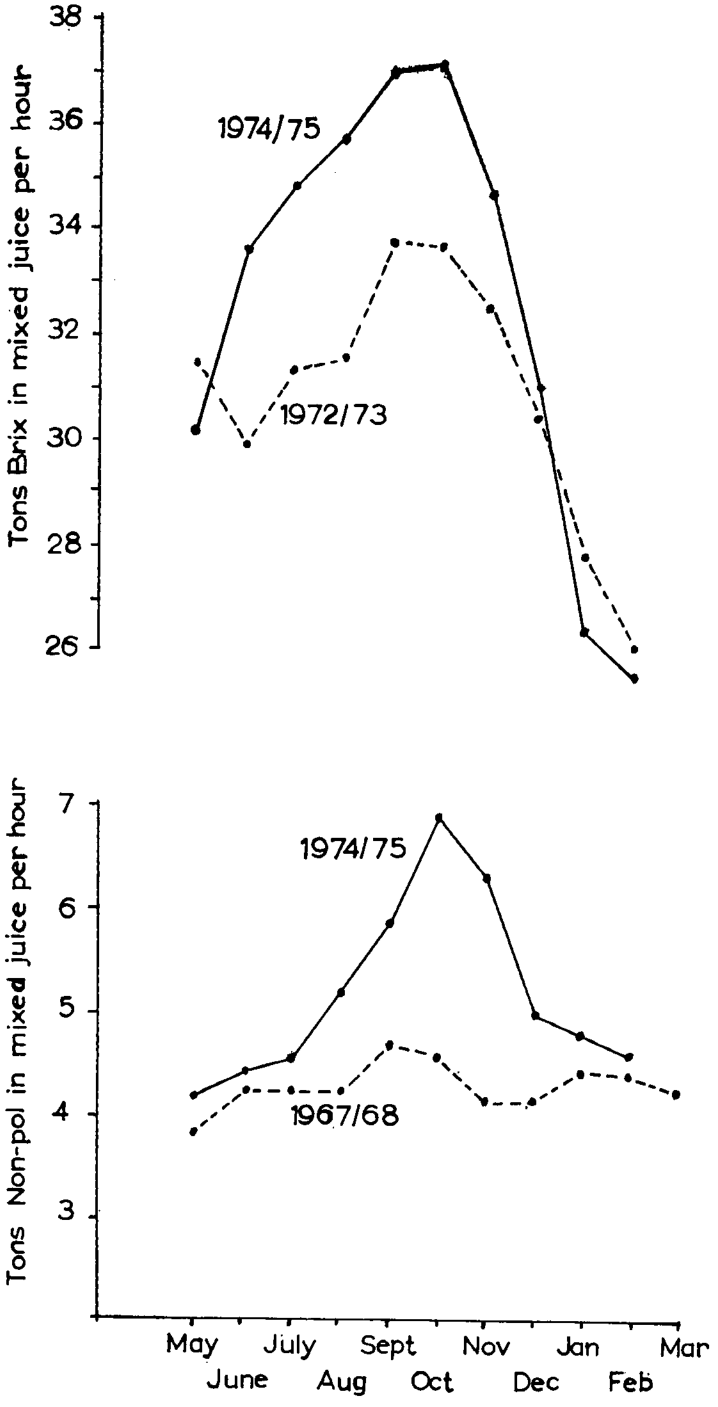


FIGURE 6 Comparison of factory loadings at Darnall in 1974 with previous maximum throughput seasons.

Although some plant changes since 1967/68 have improved capacity, particularly in the low-grade centrifugal station, the very substantial improvements last season as shown in Figure 6 are still remarkable. Discussion of their attainment will be divided into two parts; comparison with predicted values derived as described in the previous section, and a review of the measures taken to optimise boiling house plant productivity.

(1) *Comparison of actual throughput rates with calculated maxima*

In Figure 7 the calculated values for m^3 massecuite per ton brix in mixed juice, as listed in Table 1, have been used to draw the curves of unit massecuite quantity against syrup purity. Actual 1974/75 monthly values are plotted as individual points. The agreement for C-massecuite is striking. Actual results for A and B massecuite are in the same range as the calculated values but do not show any clear trend with changing syrup purity. To an extent this can be explained by the smaller change in calculated massecuite quantities with input purity for A and B. In any event the critical values are those for C-massecuite which correspond very well with the predictions in both absolute and relative terms.

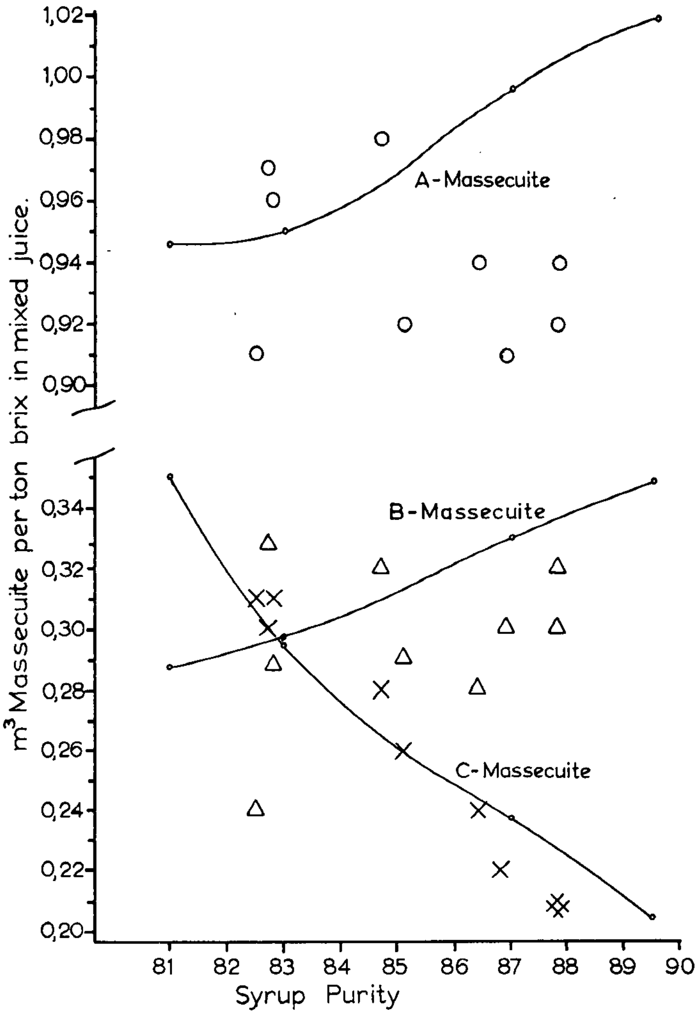


FIGURE 7 Change in unit massecuite volume with input purity
Curves — Calculated values
Points — 1974/75 monthly actual values
O — A-massecuite
△ — B-massecuite
× — C-massecuite.

Figure 8 illustrates the calculated change in pan capacity distribution between duties for different syrup purities. On this basis the drop in purity from July to October 1974 would involve a rise in pan volume employed on C-massecuite from 70 to 100 m^3. The following location plan of the Darnall pans with individual strike capabilities demonstrates that such flexibility exists. Pan volumes in cubic meters are also shown.

2	4	6	8
*	*	*	*
A(57)	AB(51)	ABC(34/28)	C(28)
1	3	5	7
*	*	*	*
A(51)	AB(34)	ABC(34/28)	C(28)

Alternative volumes are shown for 5 and 6 as the higher-grade massecuites can be boiled to 34 m^3 but 28 m^3 is the maximum for C's.

The situation whereby two of the pans can boil all three grades of massecuite is unusual. Largely as a result of this facility, flexibility of pan duty is as close as is practically possible to the ideal assumed in the calculations.

Figure 9 shows tons brix in mixed juice per hour and tons non-pol in mixed juice per hour plotted against syrup purity. As in Figure 7, the curves represent calculated values and the individual points are actual monthly data for 1974. Plots for May, January and February have been omitted as cane supply limitations were overriding in those months. During June and July when syrup purities were high and brix % cane still rising, the calculated maxima of 36,3 tons brix per hour and 4,85 tons non-pol per hour could only have been achieved had the mill crushed in excess of 240 tons cane per hour. Due to capacity restrictions in cane handling and juice treatment plant this was not possible (Darnall's capacity rating is in fact only 215 tons cane per hour). In December fibre % cane was high and the milling train was limiting even though record fibre throughput rates were achieved.

It was thus only from August to November that sufficient material could be supplied to the factory to test its throughput capabilities. Over this period the pattern of non-pol input rates agreed well with the calculated values while brix rates in fact exceeded the theoretical maxima in September and October. These rates could not have been attained without introduction of the changes described below.

(2) *Alterations to pan station plant and procedures*

The changes listed here were introduced at various times; some before the start of the season and others during the low-purity period to overcome problems that only arose then. Plant modifications are mentioned first and thereafter changes in operational technique.

(*a*) The preparation of an A-massecuite footing from B-magma is time-consuming, as the small crystal fragments resulting from the use of continuous B-centrifugals must be dissolved. A 30 m^3 vacuum receiver was removed from Huletts Refinery and installed at the end of the 1973/74 season at Darnall to hold A-grain. This allowed more strikes

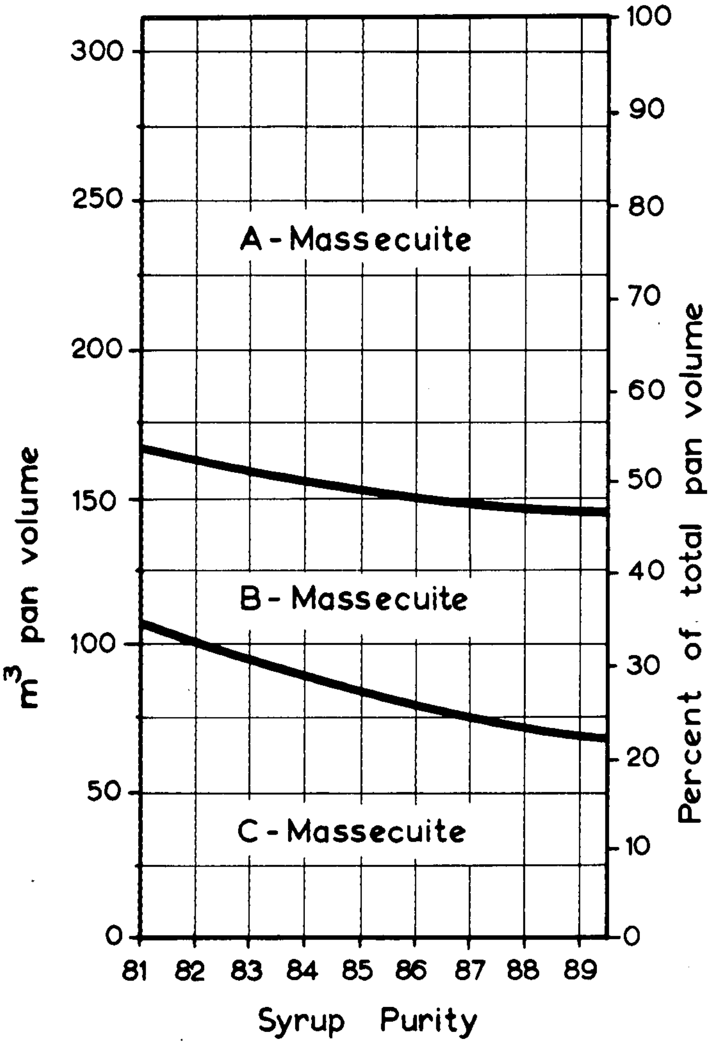


FIGURE 8 Change in distribution of pan volume between massecuite grades with input purity.

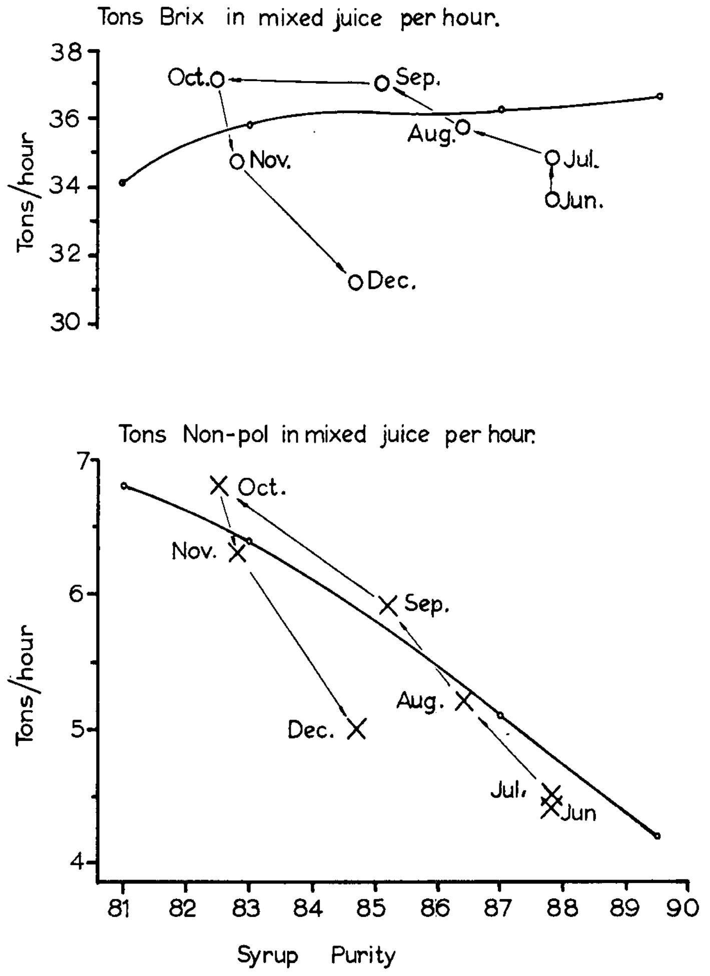


FIGURE 9 Change in maximum pan station capacity with input purity
Curves — Calculated values
Points — 1974/75 monthly actual values.

to be boiled from one magma footing, thus reducing the contribution of the washing-up process to the total A-boiling time. A further advantage was that grain could be held over the weekend stop, which enabled all the A-pans to start working as soon as the mill restarted.

(*b*) On Pan 2, one of the two used solely for A-massecuite, the vertical body section continues well above design strike volume giving a liberal head space. The feasibility of increasing the strike volume of this pan was therefore investigated. An entrainment test was first carried out. Time interval for massecuite level to rise between the last two sight glasses was measured and syrup feed continued for a similar period after full volume was reached, thus "boiling blind". Condenser tail-pipe water was monitored for sugar traces and no increase was found. An additional sight glass was then fitted and the pan boiled to the new level whenever necessitated by high factory loadings. A pan capacity increase of about 6 m^3 resulted from this step.

(*c*) Cut-over pipe size was increased from 200 mm to 250 mm and isolation valves fitted so that A, B and C massecuites and/or seeds could all be cutting at the same time. Steam (first vapour) was used to break vacuum when cutting, thus providing an increase in differential pressure (limited to the water head between the bottom of the condenser tailpipe and the seal well surface) as well as faster raising of vacuum again after cutting.

(*d*) An additional 12 m^3 graining charge tank was installed on the pan floor. Feed is directly from the A-centrifugals and overflow to the A-molasses blow-up tank, which is also fed from a bulk storage tank. The presence of the new tank meant that the large slug volume of A-molasses required for seed preparation was not diluted, was readily available and did not interfere with control of brix and temperature in the blow-up tank.

(*e*) Since Pan 7 and 8 strike only C-massecuite it was possible to replace the strike gutters with large-diameter pipes leading to the strike receiver. With the danger of overflowing gutters thereby eliminated, pan doors could be opened fully immediately on striking. Strike times were reduced from up to an hour to under ten minutes in consequence. When pressure on the C-pans became severe at very low input purities, a similar modification was carried out on Pan 5. In this case the former gutter system will have to be reverted to at more normal purities to enable Pan 5 to strike B-massecuite once more.

(*f*) The stringent grain size requirements for export sugar extend A-massecuite boiling times. The Refinery do not require a large grain size and low fines content as their affination station has been by-passed since the general introduction of VHP sugar manufacture. Arrangements were therefore made for Darnall to deliver to the Refinery only and the grain size aim was abandoned, the only limitation being that pol of sugar did not suffer. The resultant increase in A-pan output, although hard to quantify, was certainly a major factor contributing towards the higher throughputs. Darnall will regain its ability to meet export grain size specifications at high throughputs after the commissioning of a new 85 m^3 A-pan currently being installed.

(*g*) To obtain good B and C massecuite grain characteristics, it is usually necessary to maintain graining charge purity around 70. At low input purities this requires some syrup to be fed to graining charges, with a resultant increase in recirculation and slight decrease in pan station capacity. For reasons not fully understood, satisfactory grains could be produced on A-molasses alone at Darnall last year, even when purities dropped as low as 62. The same situation did not apply at the Huletts mills in Zululand, where massecuite "gumminess" was a major factor in restricting factory throughputs. Note that a minimum graining charge purity of 70 is in fact one of the brix balance constraints. The benefits in this particular case are therefore due to a slight reduction in actual massecuite quantities below predicted levels. All the other factors listed here refer to a reduction in pan operation time except for the modification to Pan 2 which represents an increase in total pan capacity.

(*h*) On occasions when the situation was critical, certain other measures that are not desirable as common practice were resorted to. These include use of B-grain for C-massecuites and vice versa, boiling C-massecuites at temperatures slightly higher than normal, and striking C-pans short of full volume.

None of the changes described above are revolutionary and it may be questioned where the merit lies in equalling, or at most only slightly exceeding, the calculated maximum capacity of the plant. It should however be realised that, firstly, the boiling time yardsticks used in the calculations are by no mean liberal and make no allowance for slack time due to out-of-balance cycles or any other cause. Secondly, reference to Figure 6 will show the rapidity with which throughput rates rose to hitherto unheard-of levels. The only major plant change on the pan floor over the past three years has been installation of the A-grain receiver. A certain reluctance on the part of operating staff to accept in the first instance the feasibility of rates well in excess of known capabilities may therefore have been expected. On the contrary, attainment of maximum throughputs at what was in effect first try, was due in large measure to the enthusiasm of the pan floor staff and their willingness to accept the challenge to maintain a crushing rate of 220 tons cane per hour.

(3) *C-centrifugal station capacity*

There can be no doubt that even with good pan flexibility, the high back end loadings would have been impossible without the powerful C-centrifugal station. As part of an investigation into forecurer capacity, five of the ten BMA K850 machines were modified to run at higher throughputs early in the season[2]. The presence of two other centrifugals installed temporarily for test purposes, a BMA K1100 and a Western States 37, also helped but throughput tests on the modified K850 machines proved conclusively that the permanent station could have handled maximum throughput without this assistance. Had the five K850's not been uprated the position would have been different. Table 4 shows that in October the C-massecuite rate was 11,5m^3 per hour. Ten unmodified machines would thus have had to handle 1,15m^3 (41 ft^3) per hour each at 100% time efficiency. Even if this rate had been physically attainable, the level of impurity recirculation would probably have risen above the reported 125%, thus increasing load on the pan house and reducing capacity there.

More significant than the difference between modified and unmodified continuous machines is that between continuous centrifugals as a class and the predecessor batch centrifugals. The non-pol rate plots for 1967/68 and 1974/75 in Figure 6 illustrate this difference. With batch machines there can be no question of throughput increases around 30% such as applied at Darnall last season. Crushing rate was severely restricted at Felixton during the low-purity period due to retention of batch centrifugals for C-massecuite. It is in fact doubtful whether the brix balances and subsequent calculations presented here for low purities would have had any relevance in the days before the introduction of continuous centrifugals for low-grade massecuites.

Effect on recoveries and molasses exhaustion

As would be expected, the low juice purities increased considerably the percentage of input sucrose that was lost in molasses. In Table 3 the inverse relationship between sucrose in molasses and mixed juice purity is evident. A drop of some 4 units of Overall Recovery can be ascribed to increase between the high- and low-purity periods in the quantity of impurity associated with incoming sucrose.

TABLE 3

Effect of juice purity on molasses losses and recovery

Month	Mixed juice purity	Sucrose in molasses % pol in cane	Overall Recovery	Ratio sucrose in molasses to non-pol in cane
May	86,0	8,3	88,0	0,440
June	86,9	7,4	89,1	0,422
July	87,0	7,1	88,9	0,408
August	85,4	8,1	88,4	0,411
September	84,1	9,3	87,2	0,430
October	81,7	11,2	85,0	0,435
November	81,8	11,1	84,6	0,429
December	83,8	10,5	84,0	0,456
January	81,8	11,3	82,6	0,425

The figures for units of sucrose in molasses per unit of non-pol in cane are reasonably steady over the season, highest value being for December when juice purity had risen somewhat and non-pol input rates were well down (note that data for February is excluded as boil-off took place during that month). A more detailed picture of molasses exhaustion performance in relation to back-end throughput appears in Table 4. Molasses purities show little trend over the season apart from slightly higher values in December and January. The low-purity period of October and November was however characterised by very high reducing sugars contents, as reflected by the ratios of reducing sugars to sulphated ash in molasses. Reducing sugars are known to facilitate attainment of low molasses purities and this is allowed for in the SMRI target purity formula. Consequently the target purity differences show poor performance from October onwards.

TABLE 4

C-massecuite throughput and molasses exhaustion

Month	m^3 C-massecuite per hour	Molasses purities			Reducing sugars/ash ratio	Target purity difference
		pol/brix	sucrose/brix	sucrose/solids		
May	6,5	31,2	36,7	38,2	1,25	0,2
June	7,1	32,0	37,4	38,2	0,99	−1,8
July	7,4	32,1	36,7	39,0	0,97	−1,2
August	8,4	31,4	36,9	38,4	1,20	0
September	9,7	31,7	37,1	39,7	1,25	1,7
October	11,5	30,4	38,0	38,4	1,70	3,0
November	10,8	31,6	37,7	38,8	1,63	3,0
December	8,6	34,6	38,6	40,5	1,38	3,3
January	8,0	33,6	37,3	40,1	1,29	2,3

The SMRI target purity formula is generally regarded as the best available yardstick for assessing molasses exhaustion performance. Its validity at high reducing sugars levels has however been questioned. In addition only reducing sugars and ash are taken into account but other non-sucrose constitutents can also affect molasses exhaustibility. As a result of the abnormal cane quality last season the characteristics of molasses then produced could well have differed significantly from those of the molasses samples used to derive the exhaustibility relationship.

It is therefore not possible to arrive at a quantitative assessment of the relationship between C-massecuite rate and molasses exhaustion. While the very high throughputs in October and November definitely accounted for some of the performance deterioration, this cannot be the sole cause as purity differences remained at a high level in December and January when factory loadings had reduced considerably.

Discussion

The need for factory loading indicators other than cane crushing rate is highlighted by the situation at Darnall last season. In October the quantity of brix entering the factory per unit of cane was 13 % above average while for non-pol the corresponding figure was 48 %. It is felt that hourly tonnages of both brix and non-pol in mixed juice represent adequate yardsticks, even though the specified analytical methods for pol and brix give value which are known to deviate from the true contents of sucrose and total solids respectively.

For a milling train, a maximum capacity in terms of tons fibre per hour can be assumed regardless of any other cane quality component. Evaluation of factory capacity is not as simple due to the alteration in proportion of the two loading indicators which follows from a change in input juice purity. Resultant capacity change effects differ for pans and centrifugals and these two departments will therefore be discussed separately.

For the estimated pan station capacities shown earlier to be attained, two main conditions must apply. The first is that pans must be able to alternate between massecuite grades to the extent required to meet the change in pan volume distribution pattern. The degree of flexibility necessary to accommodate a wide range of juice purities is often not designed for. If pan and crystalliser layout is favourable, the necessary alterations can however often be made subsequently. The second condition is the absence of so-called massecuite "gumminess" often associated with abnormal cane quality, which can be responsible for poor grain formation and extended boiling times, and enforce a rise in C-massecuite purity. A drastic reduction in attainable pan station throughput from calculated levels can result. As mentioned earlier, these circumstances applied at the Huletts Zululand mills but not at Darnall. The authors can offer no explanation for this difference.

Darnall has good pan flexibility and experienced favourable massecuite boiling characteristics last season. The calculated maximum rates could thus be reached as far as the pan station was concerned. The position with centrifugals is different. Unlike pans, centrifugals can generally not be alternated between duties to any significant extent and therefore represent a potential bottleneck at purities that differ considerably from the average. Table 2 shows that the only major massecuite rate increase when operating at maximum pan station capacity is for C-massecuite at low input purities. The reasons why the Darnall C-centrifugals were able to accommodate the higher rates have been explained. Although special circumstances applied here, it is felt that any factory with continuous C-centrifugals could provide similar overload capabilities if they do not already exist. Recent investigations have shown the very substantial throughput increases that can result from improved lubrication water mixing and molasses drainage facilities. It then remains to ensure that no physical restrictions in the C-massecuite line can become a bottleneck. The main potential culprits here are crystalliser interconnections, massecuite reheaters, pumps if they are used, and centrifugal feed piping and valves.

Continuous C-centrifugals are now very much the norm in South African factories, and hopefully the conditions necessary to achieve maximum pan station capability at low purities would apply more often than not. While it is true that the combination of high throughput requirements and low purities does not arise frequently, it would seem reasonable to make allowance for such circumstances as only relatively minor plant modifications are necessary. The conclusions to be drawn from experience at Darnall last season should therefore have a fairly general application. These are that maximum boiling house capacity in terms of brix input is virtually independent of syrup purity down to about 83. Non-pol rate on the other hand rises rapidly with declining purity — by about 60 % over the range investigated for Darnall. To a large extent this is a relatively new situation as the required high C-massecuite rates at very low input purities have only become possible since the introduction of continuous centrifugals.

Acknowledgements

The authors would like to thank Messrs C. Mack and G. Spatt for preparing the graphs, and Mr L. Jackson of the SASA Experiment Station for providing the rainfall data.

References

1. MacGillivray, A. W. and Graham, W. S. (1969). Brix determination SASTA Proc. **43**: 215–218.
2. McEvoy, M. A. and Archibald, R. D. (1975). Increased capacity of continuous centrifugals on low-grade massecuites. SASTA Proc. 49 — in press.
3. Muller, E. L. (1968). A solids balance investigation. Huletts Research and Development internal report.
4. Perk, C. G. M. (1963). Thirty-eighth annual summary of milling results — Southern African sugar factories: season 1962/63. SASTA Proc. **37**: 14–32.

Appendix I

DERIVATION OF A CORRECTION FACTOR FOR CONVERTING SUCROSE/SPINDLE MIXED JUICE PURITIES TO POL/REFRACTOMETER BASIS

The basis of the method applied here to estimate difference between sucrose/spindle and pol/refractometer mixed juice purity is the use of output quantity of impurity in sugar and molasses as a reference value. Impurity recovery ratios were found by dividing this total by tonnage of non-pol in mixed juice for seasons when the new analytical methods were in operation. The calculation method is shown below with Darnall 1972/73 data used for the example.

Tons cane	1 211 147
Pol % cane	13,37
Extraction	96,0
Mixed juice purity	87,4
Tons non-pol in mixed juice (N_j)	22 400
Tons sugar	143 699
Pol	99,50
Moisture	0,11
Tons non-pol in sugar (N_s)	560
Tons molasses	35 390
Total solids %	83,76
Sucrose %	33,29
Tons non-sucrose in molasses (N_m)	17 900
Non-sucrose recovery ratio $\dfrac{N_s + N_m}{N_j}$	0,824

Table 5 lists the 1972/73, 1973/74 and average values of non-sucrose recovery ratio for all five Huletts mills.

TABLE 5
Non-sucrose recovery ratios (pol/refractometer)

	1972/73	1973/74	Average
Empangeni	0,771	0,786	0,778
Felixton	0,760	0,782	0,771
Amatikulu	0,751	0,808	0,780
Darnall	0,824	0,837	0,830
Mount Edgecombe	0,796	0,804	0,800

The average ratios for each mill are assumed to be valid for the seasons prior to the analytical change-over. They are applied to the output impurity tonnage for previous seasons to arrive at an estimate of the quantity of impurity that would have been recorded in mixed juice, had the new methods been in effect. This tonnage together with the known quantity of sucrose in mixed juice then yields an estimated value for pol/refractometer purity. The data for the 1969/70 season at Darnall is shown in the sample calculation below.

Tons cane	1 033 022
Sucrose % cane	13,17
Extraction	95,7
Tons sucrose in mixed juice (S_j)	130 250
Tons sugar	118 720
Pol	98,08
Moisture	0,38
Tons non-pol in sugar (N_s)	1 830
Tons molasses	32 290
Solids %	79,99
Sucrose %	34,51
Tons non-sucrose in molasses (N_m)	14 690
Non-sucrose recovery ratio (pol/refracto)	0,830
Estimated tons non-pol in mixed juice $\left(N_j = \dfrac{N_s + N_m}{0{,}830}\right)$	19 890
Estimated pol/refracto mixed juice purity $\left(100 \dfrac{S_j}{S_j + N_j}\right)$	86,7
Reported sucrose/spindle mixed juice purity	84,5
Difference (units mixed juice purity) 86,7—84,5=	2,2

Table 6 lists the respective purity values and differences for the Huletts mills over the last six years of application of the old analyses.

This method suffers from an inconsistency in that the estimated pol/refractometer brix purity is given by:

$$\frac{\text{Actual } \textit{sucrose} \text{ tonnage}}{\text{Estimated non-}\textit{pol} \text{ tonnage} + \text{actual sucrose tonnage}}$$

Pol is usually slightly lower than sucrose by double polarisation, on average by about 0,05 points of percent in mixed juice. Use of sucrose in the above expression, which is unavoidable as pol tonnages are not available for past seasons, will raise the calculated pol/refractometer purity above the true figure. In fact the error so introduced is negligibly small. The form of the above expression is such that changes in the sucrose component, which is much the larger of the two, have relatively little effect on the quotient. Even a large difference between sucrose and pol % mixed juice of 0,1 units would only cause a deviation of 0,1 unit of purity from the true value.

TABLE 6

Comparison of calculated pol / refractometer (R) and reported sucrose / spindle (S) mixed juice purities

		1966/67	1967/68	1968/69	1969/70	1970	1971/72	Average
Empangeni	R	85,7	85,3	84,8	83,7	84,8	85,9	85,0
	S	83,5	82,6	82,5	82,8	83,8	83,6	83,1
	(R-S)	2,2	2,7	2,3	0,9	1,0	2,3	**1,9**
Felixton	R	86,2	85,7	86,1	85,6	85,9	86,0	85,9
	S	84,8	83,4	83,6	83,3	83,2	83,3	83,6
	(R-S)	1,4	2,3	2,5	2,3	2,7	2,7	**2,3**
Amatikulu*	R	86,7	86,3	86,2	86,3	—	87,0	86,5
	S	84,8	83,8	83,9	84,2	—	86,5	84,3
	(R-S)	1,9	2,5	2,3	2,1	—	2,1	**2,2**
Darnall*	R	88,2	86,1	86,8	86,7	86,3	—	86,8
	S	84,6	82,4	83,5	84,5	83,8	—	83,8
	(R-S)	3,6	3,7	3,3	2,2	2,5	—	**3,0**
Mount Edgecombe*	R	86,1	—	—	—	—	87,1	86,6
	S	83,7	—	—	—	—	85,5	84,6
	(R-S)	2,4	—	—	—	—	1,6	**2,0**

* Data for certain seasons at these mills cannot be included for the following reasons:

Amatikulu 1970 — cross-check of molasses weights showed discrepancy from reported figure.

Darnall 1971/72 — Abbé refractometer used to determine Brix of juice.

Mount Edgecombe 1967 to 1970 — High Test Molasses manufacture.

Some comments on the choice of data for this exercise should be made. Impurity in molasses is defined as the difference between total solids by Karl Fischer water determination and sucrose content, as reported by the Analytical Services section of Huletts Research and Development Department. Results from this laboratory were chosen as none of the changes made to their methods for sucrose and solids determination over the years concerned would have significantly affected the level of the results. Mill laboratory analyses could not be used due to the conversion from spindle to refractometer brix of molasses, which took place earlier than the change in methods for mixed juice but still within the period considered.

It will be noted that impurity recovery ratios for the 1974/75 season have not been included in the averages for the new analytical methods. Perk[4] notes that indicated recovery of impurities in the similarly drought-affected 1962/63 season was abnormally high. As these conditions occur relatively infrequently, inclusion of the possibly atypical 1974/75 ratios in an average of only three seasons could have biased this mean on the high side, thus distorting the resultant purity differences.

The purity differences in Table 2 show three high values around 3,5 for Darnall between 1966/67 and 1968/69. During independent investigations at Darnall during 1968, Muller[3] discovered that routine values for brix in mixed juice were too high due to an out-of-calibration spindle and to incorrect analytical procedure. Comparison with results from a calibrated spindle used in the proper manner indicated that mixed juice purities were being under-estimated by 0,8 units. If the three high figures are reduced accordingly, then the 24 difference values have a mean of 2,2 with a standard deviation of 0,5.

Appendix 2

BRIX BALANCES

Details of the extensive calculations required to draw up boiling house brix balances need not be given here as they appear in a number of standard works on sugar technology. The constraints applied in this case should however be noted. All sugar purities were kept constant regardless of syrup purity level. Minimum purity of graining charges for B and C massecuite was fixed at 70 which accounts for the syrup feed to these massecuites shown for the low-purity cases. C-massecuite purity was likewise not allowed to fall below 54. Massecuite exhaustions were assumed to reduce slightly with declining purities.

No distinction has been made between the forms in which B-sugar is returned to A-massecuite (as magma or remelt) since brix balances are unaffected by this difference. The aftercuring cycle contains too many unknowns for a rigorous calculation to be done and individual flows shown could be considerably in error due to incorrect assumptions. This is of little concern as effect on the all-important massecuite quantity values is small.

Finally it should be noted that pol purities have been used for all products including C-molasses. Due to the very large difference between pol and sucrose purities of final molasses at Darnall, C-massecuite exhaustions shown are some 10 units higher than those derived using sucrose molasses purity. The latter figure was therefore applied in a check Brix balance for the average syrup purity case, but the effect on massecuite quantities was found to be negligible here as well.

Appendix 3

CALCULATION OF MAXIMUM BOILING HOUSE CAPACITIES AND THROUGHPUTS

Table 1 shows the initial, intermediate and final data required in the estimation of maximum boiling house input capacities and corresponding loading rates from the brix balance figures. Nomenclature is included in the table but some points require further explanation which appears below.

The values used for solids % massecuite are lower than average brix percentages as the latter are known to err on the high side. Massecuite densities are temperature-corrected. The figure of 98,35 represents an average value for solids in syrup % solids in mixed juice.

The requirement for an indicator of massecuite boiling times has been met by the introduction of a Pan Time Index value designated t_n and defined as:

$$t_n = \frac{\text{m}^3 \text{ pan capacity employed on } n\text{th massecuite}}{\text{m}^3\ n\text{th massecuite per hour}}$$

The values of t used here are:

t_A 4,5 hours
t_B 6,0 hours
t_C 9,0 hours

These times are typical for Darnall and should be generally applicable. Note that they do not represent the interval between commencement of a boil and final strike, due to cycle overlap.

Given the assumption of adequate flexibility of pans between duties, maximum factory input rate and distribution of pan capacity between massecuite grades can now be calculated as shown below.

If: C_n = m^3 pan capacity employed on *n*th massecuite
V_n = m^3 *n*th massecuite per ton brix in mixed juice
then from the definition of Pan Time Index t_n above, it is obvious that

$$\frac{C_n}{t_n V_n} = \text{Tons brix in mixed juice per hour (B)}$$

Using the average-purity case as an example, we have

$$B = \frac{C_A}{4{,}5 \times 0{,}996} = \frac{C_B}{6{,}0 \times 0{,}330} = \frac{C_C}{9{,}0 \times 0{,}237}$$

and

Total pan capacity $C_A + C_B + C_C = 311{,}5$

These equations solve to:

B = 36,2 tons/hour
C_A = 162 m^3
C_B = 72 m^3
C_C = 77 m^3