A STATISTICAL ANALYSIS OF INDUSTRY DATA WITH PARTICULAR REFERENCE TO THE LOW GRADE END OF FACTORY OPERATIONS

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Abstract

Industry data from the low grade end of the factory have been statistically analysed with a view to deriving empirical relationships that could be of assistance in two important areas: (*a*) evaluation of factory performances and (*b*) provision of new insights into the significance of operating variables and techniques. Based on the industry data, the best fit equation for evaluating backend performance takes the following form:

Molasses true purity = 39,82 — 15,91 log (Rs/a)

An equation of this form indicates that the factories with high Rs/a ratios have greater difficulty achieving target purity than do their low RS/a ratio counterparts and this suggests that the existing SMRI log formula could be marginally biased in favour of the low Rs/a ratio operator. Regarding correlations, it has been established that a very strong relationship exists between molasses true purity and C-massecuite purity: with a one unit change in the latter being equivalent to 0,3-0,35 units of true purity in the average case.

Introduction

In South Africa factories pol losses in molasses are substantial, averaging out at approximately 8,5% on pol in cane. This represents by far the largest single factor in relation to overall recoveries. For this reason, process personnel at all levels devote considerable time and energy to the backend of the factory in an endeavour to minimize losses.

In line with practice followed in other parts of the world, notably Australia and Hawaii, the South African sugar industry has set about developing its own standard for measuring and comparing the performances of individual factories. In 1973 the Sugar Milling Research Institute recommended the use of the following relationship as a standard for evaluating molasses exhaustion:

Target (true) purity = 39,94 — 19,6 log (Rs/a)

While the SMRI log formula has proved of great value to the Industry it has at the same time come in for a fair amount of criticism in regard to its apparent inequity at high reducing sugars/ash ratios.

The present statistical analysis was undertaken with a view to (i) checking out the validity of this claim and (ii) identifying the process variables (physical as well as chemical) that influence the achievement of optimum backend performances and results.

Discussion

Evaluation of Factory Performances

Background comments on source of the input data and evaluation technique used

The data presented in Figures 1-3 have been obtained from routine laboratory analyses performed on final molasses composite samples. These data cover the vast bulk of the season's results, with only one or two data points excluded at each end of the season. This excision has been made to ensure that the quality of the final product is not affected by the a-typical results normally associated with factory startup and liquidation.

The approach adopted in the preparation of these figures has been to select a number of operating variables that could possibly affect the molasses true purity and, in turn, the target (true) purity difference, and to statistically test their significance both singularly or in combination with each other.

Analysis of data from Huletts' factories (normal conditions: 1975/76)

In reference specifically to Figure 1, it is readily apparent that the Rs/a ratio is the only factor that is of any real significance with respect to molasses true purity. This same trend is discernable for all the Huletts' factories and is a most gratifying result. Taking Empangeni as example, the correlation coefficient/"t"-value of the coefficient, are respectively 0,791/7,31. Both these values are significant at above the 0,1% level. Furthermore it is noteworthy that combining the Rs/a ratio with almost any other variable viz. MJ purity, C-massecuite purity, equipment loading, makes practically no difference to the correlation coefficient; which rises to only 0,798 in the maximum case.

Again in reference to Figure 1, it is equally apparent that in no instance does the Rs/a ratio exert a significant effect on the target purity difference. In considering target purity difference, as opposed to true purity, it is important to note that the SMRI log formula should successfully eliminate all vestiges of the influence of Rs/a ratio; and any general evidence of residual Rs/a effects must be seen as a measure of the log formula's inability to fulfil its role. In the event, the formula is fully vindicated and the results shown in Figure 1 are much as expected.

Analysis of data from Huletts' factories (abnormal conditions: 1974/75)

During the second half of the 1974/75 season (mid September to the end of the crop), the full force of the 1973/74 drought manifested itself with drought stressed and fire cane accounting for the bulk of the supplies to a number of factories. The factories principally affected were the four northern Natal mills owned by Huletts, namely: Darnall, Amatikulu, Felixton and Empangeni. The midlands factories also suffered to a greater or lesser extent. In all these factories juice purities plunged between 3 and 7 units and besides the obvious adverse effect that a change of such magnitude would have on recoveries, the position was further aggravated by the presence of refractory juices which gave rise to poor boiling characteristics.

In Figure 2, data are presented for the 1974/75 season and reveal a very different picture to that seen in the 1975/76 season already discussed. Not only is the correlation coefficient between Rs/a ratio and true purity much lower than previously but also there is a very substantial residual effect of the Rs/a ratio on target purity difference. In point of fact, the correlation is very much better for Rs/a — target purity difference than for Rs/a — true purity. This is clearly in conflict with the format of the SMRI log formula and demonstrates the inapplicability of this formula to situations that vary grossly from "normality". In this context it is of passing interest that a single sample of final molasses drawn from Amatikulu factory about this time, and which was subjected to a boiling down test at the SMRI, could do no better than approach target by + 4,5 units following exhaustion under standard laboratory conditions. That this leads one to the inescapable conclusion that the SMRI formula does not apply under all circumstances should not be regarded as in any way heretical or even unusual: the only new feature is that speculation and fact have been brought somewhat closer together.

Analysis of all industry data

One of the major disadvantages inherent in analysing data from individual factories is that the spread in the operating variables is frequently small and this lack of resolution makes it difficult if not impossible to obtain a realistic picture of the "effect" of such variables on the overall result.

One means of overcoming this type of problem is to look at data emanating from a large number of sources (such as all the factories in the industry) but even here the technique is not without problems; notably the considerable increase in the background "noise" introduced by such factors as differences in equipment and technique applied at the various factories. However, looking on the positive side, inclusion of data from all the factories does imply a vast increase in the number of data sets and seen from the statistical point of view this can only mean that such trends as do emerge can be accepted with a greater degree of confidence.

Figure 3 is to be seen in the light of the above remarks. Before discussing the results given in Figure 3, it is considered important that a few words be said regarding the input data that has been included. Noteworthy points are:

(i) the primary source data are analyses performed monthly by the SMRI laboratories on a weekly composite sample of molasses provided by each factory (third week of the operating month)
(ii) consistent operating data is obtained from the SMRI publication "weekly summary of data" (the third week of the operating month again applying)
(iii) the results of Malelane, Union Co-op and Entumeni factories have been excluded throughout as they appear to be incompatible with the balance of the data
(iv) the results relate to the 1974/75 and 1975/76 seasons
(v) the mass of the data have been processed in two sections —
   - all the Industry data, consisting of 230 data sets and
   - abridged Industry data, consisting of 207 data sets, from which the results of DL, AK, FX, EM, JB and GD covering the period October 1974-February 1975 have been excised. The reasons for this decision appear in the earlier discussion.

Some of the more important results of this study are given as follows:

(*a*) the decision to separate the abnormal data from the normal data appears to have been fully justified in as much as the quality of the product is uniformly improved by this means. This effect is to be seen most noticeably in the case of the correlation coefficients but also, to a lesser extent, in the dispersion of the results. (see item 2 of Figure 3). *Accordingly, the smaller data set is regarded as the more representative and is exclusively referred to in the subsequent discussion, irrespective of whether this fact is stated or not.*

(*b*) the very low correlation coefficient existing between backend loading and Rs/a ratio. This finding is completely in line with the results obtained for Huletts' factories operating under normal conditions.

(*c*) the very low correlation existing between the Rs/a ratio and target purity difference. This result, together with the good correlation existing between the Rs/a ratio and true purity, is further verification of the soundness of a performance formula based on the Rs/a ratio.

(*d*) the marginally better results obtained for the correlation of true purity with log Rs/a as opposed to a direct Rs/a relationship. Comparison of the values derived for the correlation coefficient/t-value of the coefficient, are respectively 0,595/9,32 versus 0,537/9,10. Again this finding is in line with the experimental work done by the SMRI.

(*e*) the strong correlation found between C-massecuite purity and both true purity and target purity difference. The similarity in the size of the coefficient in these two cases lends strong support to the belief that the correlation is a genuine one.

(*f*) the fair correlation found between backend loading and both true purity and target purity difference. Again the similarity in the size of the correlation in these two cases is a favourable factor.

(*g*) the relationships of maximum correlation found between a combination of Rs/a ratio, C-massecuite purity on the one hand and true purity (or target purity difference) on the other. With reference to the latter relationship it is, however, noteworthy that the variable that correlates most strongly is C-massecuite purity and the appearance of the Rs/a ratio term in a marginally improved grouping could then be due to its residual influence or more probably via some indirect correlating route.

Having discussed the main features of Figure 3 it only remains to look at the form of some of the relationships and to consider their practical implications. This is done in more detail in some of the following sections.

The SMRI log formula

In Figure 3 the best fit relationship between the Rs/a ratio and true purity is an equation of the form:

$$\text{Molasses true purity} = 41{,}59 - 15{,}91 \log (\text{R/sa})$$

This relationship is empirically derived from Industry data, and makes no claim at being the optimum level of attainment. On the contrary, factory results on the average are almost guaranteed to fall short of a standard performance level that has been established in terms of the SMRI log formula.

What is then required for a direct comparison to be made between the factory derived formula and the SMRI log formula is some levelling technique. It is here contended that the mean target purity difference for the industry could perform this role. Adjustment of the factory data by this figure, namely +1,77 units, alters the factory derived formula as follows:

$$\text{Molasses target purity} = 39{,}82 - 15{,}91 \log (\text{Rs/a})$$

The form of this equation is now very similar to the SMRI formula, the only significant difference being the slope of the lines.

The various equations are plotted in Figure 4. If it is accepted that the difference in slope between the two lines is genuine then the implication of this finding is that factories with high Rs/a ratios are prejudiced in respect of their attempt at achievement of target purity whereas operators with low Rs/a ratios are favoured. Attaching actual values to this, it would appear that there is a bias of about 0,8 unit of purity on comparison of factories with Rs/a ratios differing by 0,5 of a unit.

One or two additional comments need to be made in relation to Figure 4. Firstly, in some quarters it may be thought that the adjustment of the factory derived formula by the

STATISTICAL ANALYSIS OF 1975/76 SEASON RESULTS

	EMPANGENI	FELIXTON
1. Number of Data Sets . . .	32	34

2. Summary of Results

	Empangeni: Mean of results	Empangeni: Range of results	Empangeni: Standard deviation	Felixton: Mean of results	Felixton: Range of results	Felixton: Standard deviation
Mixed juice purity	85,01	4,2	1,08	85,45	3,8	0,88
C-massecuite purity . . .	56,18	4,3	1,19	60,07	3,1	0,74
Backend loading	100	42	11	100	27	7
RSA ratio in molasses . .	0,94	0,35	0,08	1,13	0,48	0,11
True purity of molasses . .	42,50	5,5	1,21	43,49	3,9	1,13
Target purity difference . .	2,02	2,9	0,76	4,57	2,5	0,69

3. Statistical Analysis of Data (correlation coefficients & Significance Levels)

	Empangeni: True purity of molasses		Empangeni: Target purity difference		Empangeni: Other variables	Felixton: True purity of molasses		Felixton: Target purity difference		Felixton: Other variables
	Corr Coeff	t value	Corr Coeff	t . value	Corr Coeff	Corr Coeff	t value	Corr Coeff	t value	Corr Coeff
RSA ratio	0,791	7,31	0,267	1,56		0,815	7,96	0,241	1,41	
RSA ratio/m.j. purity . . .	0,793		0,283			0,816		0,246		
RSA ratio/c-mass. purity . .	0,795		0,309			0,816		0,258		
RSA ratio/loading	0,791		0,270			0,822		0,257		
RSA ratio/m.j. pty/c-mass pty	0,798		0,328			0,817		0,229		
RSA ratio/loading/c-mass pty	0,794		0,285			0,824		0,274		

STATISTICAL ANALYSIS OF 1974/75 SEASON RESULTS

	EMPANGENI	FELIXTON
1. Number of Data Sets . . .	39	41

2. Summary of Results

	Empangeni: Mean	Empangeni: Range	Empangeni: Standard deviation	Felixton: Mean	Felixton: Range	Felixton: Standard deviation
Mixed juice purity	84,52	5,3	1,87	84,36	7,8	2,18
C-massecuite purity . . .	55,89	5,5	1,30	60,06	3,6	0,68
Backend loading	100	42	11	100	27	7
RSA ratio in molasses . .	1,04	0,54	0,16	1,16	0,77	0,19
True purity of molasses . .	42,40	4,9	1,04	43,00	4,2	0,91
Target purity difference . .	2,68	5,1	1,35	4,19	4,8	1,26

3. Statistical Analysis of Data (Correlation Coefficients and Significance Levels)

	Empangeni: True purity of molasses		Empangeni: Target purity difference		Empangeni: Other variables	Felixton: True purity of molasses		Felixton: Target purity difference		Felixton: Other variables
	Corr Coeff	t value	Corr Coeff	t value	Corr Coeff	Corr Coeff	t value	Corr Coeff	t value	Corr Coeff
RSA ratio	0,406	2,32	0,698	5,55		0,498	3,58	0,771	7,56	
RSA ratio/m.j. purity . . .	0,630		0,778			0,499		0,772		
RSA ratio/c-mass pty . . .	0,472		0,701			0,607		0,810		
RSA ratio/loading	0,433		0,690			0,538		0,785		
RSA ratio/m.j. pty/c-mass pty	0,648		0,809			0,608		0,810		
RSA ratio/loading/c-mass pty	0,473		0,703			0,607		0,810		

(HULETTS FACTORIES) FIGURE 1

AMATIKULU			DARNALL			MT. EDGECOMBE		
35			33			32		
Mean of results	Range of results	Standard deviation	Mean of results	Range of results	Standard deviation	Mean of results	Range of results	Standard deviation
84,47	4,1	1,12	85,75	3,6	0,88	84,36	3,0	1,02
55,48	7,2	1,98	53,31	3,8	0,82	56,27	4,6	1,03
100	60	10	100	38	8	100	44	14
1,14	0,80	0,17	0,95	0,51	0,11	1,32	0,66	0,20
41,99	8,1	1,94	42,02	4,7	1,34	39,41	7,3	2,08
3,05	4,3	1,26	1,60	3,6	1,04	1,78	5,5	1,40

True purity of molasses		Target purity difference		Other variables	True purity of molasses		Target purity difference		Other variables	True purity of molasses		Target purity difference		Other variables
Corr Coeff	t value	Corr Coeff	t value	Corr Coeff	Corr Coeff	t value	Corr Coeff	t value	Corr Coeff	Corr Coeff	t value	Corr Coeff	t value	Corr Coeff
0,770	6,83	0,187	1,08		0,613	4,25	0,179	1,00		0,750	6,11	0,231	1,28	
0,799		0,373			0,714		0,477			0,754		0,264		
0,755		0,213			0,614		0,181			0,753		0,248		
0,771		0,179			0,630		0,263			0,757		0,249		
0,802		0,384			0,715		0,453			0,755		0,255		
0,772		0,224			0,631		0,266			0,758		0,254		

(HULETTS FACTORIES) FIGURE 2

AMATIKULU			DARNALL			MT. EDGECOMBE		
36			38			36		
Mean	Range	Standard deviation	Mean	Range	Standard deviation	Mean	Range	Standard deviation
83,01	8,6	2,73	84,16	6,6	2,12	85,18	2,3	0,59
56,98	8,3	1,56	53,97	3,3	0,76	56,18	3,7	0,93
100	60	10	100	38	8	100	44	14
1,42	0,97	0,23	1,30	0,98	0,26	1,25	0,38	0,09
39,79	6,6	1,72	38,93	4,4	1,01	39,46	7,3	1,80
2,75	9,8	2,53	1,06	7,0	1,96	1,42	7,2	1,74

True purity of molasses		Target purity difference		Other variables	True purity of molasses		Target purity difference		Other variables	True purity of molasses		Target purity difference		Other variables
Corr Coeff	t value	Corr Coeff	t value	Corr Coeff	Corr Coeff	t value	Corr Coeff	t value	Corr Coeff	Corr Coeff	t value	Corr Coeff	t value	Corr Coeff
0,346	2,15	0,770	7,04		0,041	0,24	0,831	8,96						
0,690		0,877			0,343		0,855							
0,355		0,774			0,107		0,832							
0,611		0,841			0,053		0,831					not appl	icable	
0,691		0,877			0,347		0,855							
0,628		0,850			0,108		0,832							

STATISTICAL ANALYSIS OF 1974/75 SEASON'S RESULTS (ALL S.A. FACTORIES) FIGURE 3

1. Number of Data Sets

	All industry data	All industry data (excluding results of DL, AK, FX, EM, JB, GD from October to end of 1974/75 season)
	230	207

2. Summary of Results

	Mean of results	Range of results	Standard deviation	Mean of results	Range of results	Standard deviation
Mixed juice purity	85,00	6,88	1,47	85,27	5,52	1,20
C-massecuite purity	55,20	14,44	2,64	55,17	13,25	2,63
Backend loading	100	96	19	100	96	19
RSA ratio in molasses	1,16	1,38	0,23	1,14	1,25	0,21
True purity of molasses	40,83	14,99	2,23	40,80	14,99	2,28
Target purity difference	1,98	10,38	1,93	1,77	9,43	1,83

3. Statistical Analysis of Data (correlation coefficients and significance levels)

	True purity of molasses		Target purity difference		Other variables	True purity of molasses		Target purity difference		Other variables
	Corr coeff	t value	Corr coeff	t value	Corr coeff	Corr coeff	t value	Corr coeff	t value	Corr coeff
RSA ratio[b]	0,473	8,11	0,260	4,06		0,537	9,10	0,117	1,69	
RSA ratio/c-mass pty[d]	0,642	8,38/8,52	0,535	5,45/8,33		0,678	9,12/8,07	0,496	3,08/7,93	
RSA ratio/m.j. purity	0,480	7,92/1,39	0,297	2,69/2,27		0,537	8,33/0,24	0,135	1,12/0,98	
RSA ratio/backend loading	0,474	8,03/0,51	0,260	3,91/0,28		0,537	8,99/0,04	0,117	1,68/0,12	
RSA/c-mass pty/m.j. pty	0,648	8,34/8,58/1,73	0,555	3,79/8,49/2,73		0,680	8,68/8,11/0,91	0,507	2,10/8,08/1,75	
RSA/c-mass pty/loading	0,644	8,42/8,55/1,00	0,536	5,20/8,35/0,72		0,680	9,15/8,11/0,85	0,497	2,97/7,94/0,65	
C-mass purity[c]	0,479	8,25	0,438	7,37		0,490	8,05	0,459	7,40	
C-mass purity/m.j. purity	0,491	8,17/1,85	0,514	7,97/4,73		0,513	7,75/2,50	0,491	7,84/2,84	
C-mass purity/loading	0,481	8,18/0,59	0,450	7,49/1,69		0,490	7,95/0,26	0,463	7,47/1,01	
M.j. purity	0,135	2,05	0,243	3,78		0,214	3,14	0,111	1,60	
Loading	0,067	1,01	0,070	1,06		0,074	1,06	0,008	0,12	
M.j. purity/loading	0,149	2,03/0,98	0,752	3,76/1,01		0,227	3,14/1,09	0,111	1,59/0,12	
M.j. purity vs. RSA ratio					0,439					0,423
M.j. purity vs. loading					0,021					0,002
RSA ratio vs. loading					0,202					0,142
Log RSA[a]	0,498	8,66				0,545	9,32			

Note:

(*a*) True purity =	41,61 — 13,33 log (RSA)	41,59 — 15,91 log (RSA)
(*b*) True purity =	46,15 — 4,57 (RSA)	47,51 — 5,90 (RSA)
(*c*) True purity =	—	—
(*d*) True purity =	25,32 — 4,14 (RSA) + 0,368 (C-mass purity)	26,65 — 5,21 (RSA) + 0,364 (C-mass purity)
(*a*) TP difference =	—	—
(*b*) TP difference =	—	—
(*c*) TP difference =	— 15,69 + 0,320 (C-mass purity)	— 15,90 + 0,320 (C-mass purity)
(*d*) TP difference =	— 19,93 + 2,56 (RSA) + 0,343 (C-mass purity)	— 18,89 + 1,67 (RSA) + 0,340 (C-mass purity)

N.B.—The degrees of freedom (number of data sets less variables being compared) have the following cut-off values:

Degrees of freedom	30			100		
Confidence level	95	99	99,9	95	99	99,9
Correlation coefficients	0,35	0,45	0,55	0,195	0,254	0,321
t value of coefficients	2,04	2,75	3,65	1,98	2,62	3,37

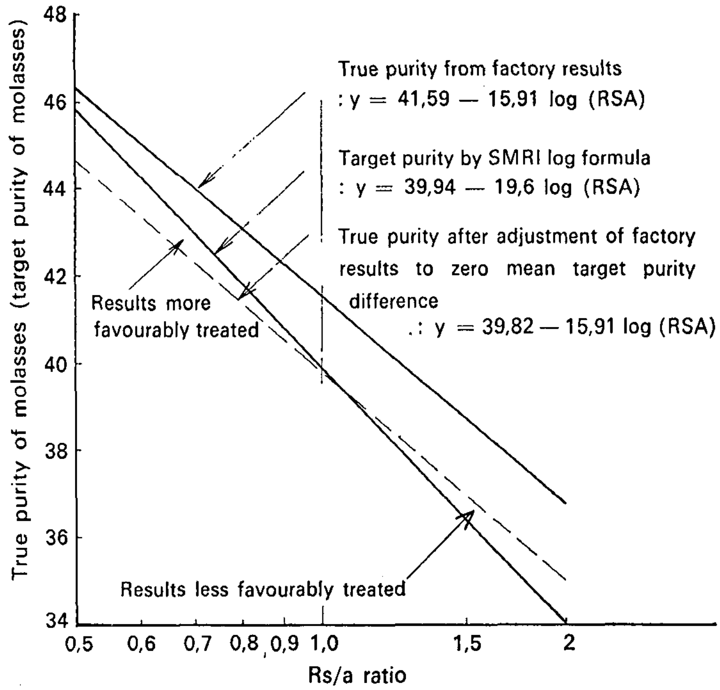

FIGURE 4 Relationship between Rs/a ratio and molasses purity derived empirically from factory results.

mean of the target purity differences is in the nature of being a gimmick to bring the two formulae onto common ground. This is a debatable point, but at the same time it is not really material to the main argument which concerns itself more with comparative values than absolute values. In other words, the slope of the line is the important figure rather than the intercept, and the levelling technique does not involve any change being made to the slope. It should also be borne in mind that to the operator, and all those other personnel looking at the results, the real concern in regard to performance evaluation is that the efforts of each factory be treated equally and this is nowhere more true than of cases (such as this one) where no absolute level of performance does in fact exist.

The second point meriting comment relates to the possibility that the slope of the line based on the factory derived formula is itself influenced by outside factors. Again this is perhaps a debatable point, but study of the data appearing in both Figures 1 and 3 goes some of the way towards dispelling such a belief. From these data is it apparent that the variable often regarded as the most likely to be related to the Rs/a ratio, namely backend loading, in fact shows a very low correlation.

Evaluation of Operating Variables

The effect of backend loading on factory performance

As defined in Figure 3, backend loading is the tons non pol in mixed juice taken as a percentage of the mean value for the season. However, the method suffers from various shortcomings, notably the use of "tons non pol" as the measure of backend throughput. In fact, this gives only a rough indication of backend loading since no cognizance is taken of either stock changes (which directly affects throughput) or the differences in the amount of equipment installed at each individual factory (which directly affects residence time). In other words a factory that is very generously endowed with pan and crystallizer capacity is unlikely to feel the effect of gross changes in throughput to anything like the same degree as another factory that is marginally placed with respect to installed equipment.

The above lists some of the imperfections of the technique employed, but under the circumstances there was limited choice as very little was available by way of alternatives.

In Figure 3 equations are presented which show the influence of C-massecuite purity. The relevant equations are:

True purity = 26,65 — 5,21 (Rs/a) + 0,364 (C-mass. pty)
also
Target purity difference = — 15,90 + 0,320 (C-mass pty)

On basis of the results in Figures 1, 3 it appears that backend loading has no significant effect on results. It is of course extremely difficult to test the validity of a statement of this type. In the context of the Huletts' factories an effort has been made to cross check the result by looking at what happens to molasses purities on the first processing day after the routine weekend shutdown. On average the shutdown is of about 16 hours duration which implies an extra C-massecuite residence time of the order 50% in the crystallizers. Unfortunately no similar type check is possible in regard to pan floor loadings but, in general, any inadequacies suffered at the pan boiling stage can be made-up for in the crystallizers. In the light of these comments the inability to check pan loadings was not taken too seriously.

In Figure 5 data is presented which has been built up from daily analysis produced by the four Huletts' factories having continuous low grade stations. From the tables it is apparent that only one factory, Darnall, shows molasses purities that are significantly lower during the first day of operation following the routine shutdown as compared with the average for the week. The only logical conclusion to be drawn from these figures is that additional molasses exhaustion can occur as a result of the extra residence time in the crystallizers but why only one factory should be so affected is somewhat more difficult to explain away.

One possible explanation, even though somewhat tentative, is that Darnall produces an extremely high brix massecuite (> 98° refractometer) which is significantly above the figure that is generally achieved in the industry. The corollary of high brixes is, of course, high viscosities and it is quite possible that the average crystallization rates evidenced at Darnall are so low that any additional time spent by the massecuite in the crystallizers results in improved results. By the same token the other Huletts' factories, by applying lower brix levels, do not show similar effects.

The effect of C-massecuite purity on factory performance

In the preceding section, formulae are given which equate true purity and target purity difference with C-massecuite purity. The real value of these equations lies in the fact that the constant term associated with each variable gives a measure of effect of any change made to that variable. As is apparent from the equations the constant term in the case of C-massecuite purity is of the order 0,34, i.e. a one unit change in C-massecuite purity will produce a change of 0,34 units in the molasses true purity. A downward movement of 5 units could then be expected to yield a reduction in the molasses true purity of 1,7 units in the average case.

The evaluation detailed in Figure 3 represents, in a real sense, a definitive set of answers. However, it does not offer the benefit of perspective and to this end the graphs shown in Figure 6 have been prepared in addition. These graphs show the influence of C-massecuite purity on target purity difference for the periods 1972/74 and 1974/76 and have been built up from annual factory averages. Both graphs are significant at the 0,1% level. A further matter of interest here is the fact that the scatter in the target purity difference values is of the same order as the reproducibility of the analytical results (*vide* SMRI/Huletts R & D comparisons made each month on identical molasses sample which appears in Figure 7) and this additionally strengthens the view that the graphs are a fair approximation to reality. The slope of the 1974/76 line, at 0,36, is also much the same as before and implies an overall gain of 1,8 units in true purity associated with a 5 unit drop in C-massecuite purity.

TABLE OF C CRYSTALLIZER PERFORMANCES — FIGURE 5

	MT. EDGECOMBE			DARNALL			AMATIKULU			EMPANGENI		
	Mean purity diff.	Standard deviation	Significance (%)	Mean purity diff.	Standard deviation	Significance (%)	Mean purity diff.	Standard deviation	Significance (%)	Mean purity diff.	Standard deviation	Significance (%)
Purity Difference Day 1 versus Average of Days 2 and 3—												
1973/74	0,12	0,95	none	0,40	0,69	between 1 and 0,1	0,11	1,04	none	0,04	0,65	none
1974/75	0,22	0,77	none	0,41	0,60	> 0,1	0,59	1,01	> 0,1	0,09	0,63	none
1975/76	(0,01)	0,67	none	0,72	0,71	> 0,1	0,24	1,04	none	0,17	0,89	none
Purity Difference Day 1 versus Average for Week—												
1973/74	—	—	—	—	—	—	—	—	—	—	—	—
1974/75	0,14	0,89	none	1,06	0,59	> 0,1	(0,98)	1,38	> 0,1	0,71	1,11	> 0,1
1975/76	(0,02)	0,56	none	0,66	0,66	> 0,1	0,34	0,97	5	0,05	1,04	none

Note: A significance of 0,1% implies a 99,9% level of confidence for the statement that "there is a genuine difference between the two sets of data and that the observed difference (shown in the table) is not fortuitous" . . . etc.

Figures in brackets indicate a higher molasses purity on day 1 than on subsequent days.

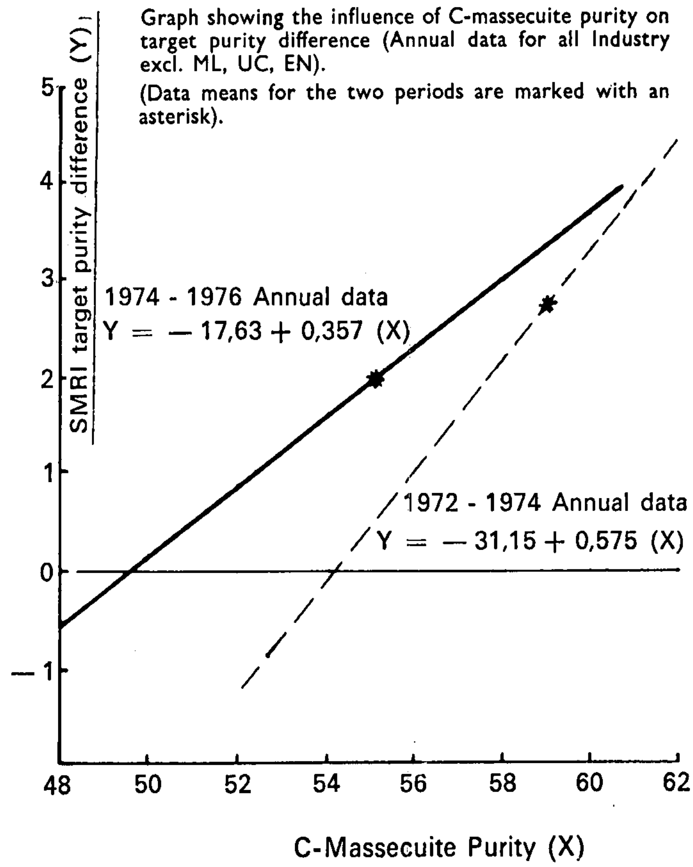

FIGURE 6 Relationship affecting backend performances.

In the course of preparation of Figure 6 some additional data was produced which is shown below:

	SEASON			
	1972/73	1973/74	1974/75	1975/76
Mean C-massecuite purity . .	59,74	58,20	56,07	54,75
Mean (period average) . . .	59,0		55,1	
Mean target purity difference .	2,9	2,7	2,1	1,9
Mean (period average) . . .	2,8		2,0	

This shows that over a four year period C-massecuite purities have been reduced by approximately 5 units (59,74 → 54,75) to yield a reduction in target purity difference of 1 unit in the average case. These figures could possibly be regarded as an indication of the overall improvement level achieved by the industry as a result of modernization of the low grade stations. If this interpretation is basically valid, then it shows that considerable scope still remains for bringing these modernized facilities up to their full potential.

There is, of course, another side to the low C-massecuite purity saga and this is the effect it has on the quantities of material being boiled. For instance, if the purity of C-massecuite could be reduced by 5 units, from say 55 to 50, the corresponding reduction in the quantity of C-massecuite required to be boiled would be of the order 20%. Quite obviously the additional benefits accruing from a change of this magnitude would be very considerable.

The effect of C-massecuite brix on factory performance

One of the unfortunate omissions from the present study relates to C-massecuite brix. This situation has come about as a result of the non-inclusion of this value in the routine industry returns. However, the fact that no firm recommendations can be made in regard to massecuite brix in no way implies that there should be no comment passed on the subject.

Just as the position regarding massecuite purities is fairly clear-cut, the position regarding massecuite brixes is unclear.

Until fairly recently it was generally held that the optimum brix level at which to operate was the highest brix that could be satisfactorily handled in the available equipment. In other words, where circumstances permitted, the maxim: "the tighter the massecuite, the better the results" went unchallenged; and the excellent results achieved at Darnall provided strong support for such a view. Furthermore, the work of Prinsen Geerligs, which has been supported by subsequent researchers in this field, indicates that lowest final molasses purity figures are achieved when non-sucrose/water ratios are highest. What this says in effect is that the production of C-massecuites of highest brix and lowest purity should be the aim of every factory.

However, some of the best results now being achieved have not involved high brixes and hence some of the old doubts return to taunt the operator. Is it reasonable to expect best results under conditions wherein brixes and, in turn, viscosities are maximized? (Reference to the section on backend equipment loading suggests that the answer could be "no" under certain circumstances.) Also, are the findings of Prinsen Geerligs still applicable to the very low purity/very high brix massecuites that have become standard in the Industry since the advent of the continuous centrifugal?

Obviously there is considerable scope for further investigation in this area.

Conclusions

The contents of this paper may be divided into two main parts:

(*a*) discussion concerning a factory derived equation for evaluating backend performance, and

(*b*) discussion concerning operating variables that have a practical implication for the factory.

In regard to performance evaluation, the present work does three things: firstly it fully endorses the choice of the Rs/a ratio in the log form as an equitable correlating variable for application under all "normal" conditions; secondly it demonstrates that the SMRI log formula has definite limitations and does not apply to instances when drought stressed/fire cane is processed (although it should be noted that this is entirely in line with reasonable expectation); and thirdly it suggests that the existing SMRI log formula is marginally biased in favour of the operator with a low Rs/a ratio. In regard to the last point, it is felt that some additional work should be undertaken by the SMRI so that anomalies of this type, if true, can be eliminated.

Turning next to the more practical implications of the paper's findings, three points are noteworthy: firstly there is clear evidence that for the factory with a continuous low grade station, production of C-massecuite of the lowest achievable purity is likely to give the best results. Based on the present study, an improvement of approximately 0,3-0,35 true purity points is to be expected from a one unit drop in C-massecuite purity. In order to achieve this result it should, however, be borne in mind that any move to lower C-massecuite purities will probably have to start right back at the A boiling stage since A/B exhaustions of around 65% are unlikely to yield a B molasses product of sufficiently low purity. Secondly, it appears that loadings can have an effect on performance and the factory that is well endowed with equipment will do better than its counterpart that is less well off. However, a word of caution would not seem out of place here. Since there is inevitably a trade-off between "excellence of operating results" and "size of capital outlay" it will be necessary to consider each case on its merits in deciding on the location of the economic optimum. And this of course is a matter best left to individual factories to determine for themselves. Thirdly, and lastly, the question of "which brix level is best" still remains to be answered. Perhaps the only suggestion that can be made at the present time is to aim as high as practically possible, consistent with equipment capabilities.

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TABLE OF INTERLABORATORY COMPARISONS FIGURE 7

		Dry Solids (%)	Sucrose (%)	True purity	Red Sugars (%)	Ash (%)	RS/A Ratio	T.P. Diff.
1974/75	Number of samples	←			45			→
	Means: Huletts RD ($\bar{x}_1$)	81,16	33,18	40,95	17,78	14,68	1,23	2,51
	SMRI ($\bar{x}_2$)	81,47	33,55	41,19	17,10	14,86	1,17	2,37
	Difference ($\bar{d}$)	− 0,31	− 0,37	− 0,24	0,68	− 0,18	0,06	0,14
	Standard deviation (σ_d)	0,91	1,15	1,59	1,10	0,46	0,10	1,59
	Coefficient of variation ($100\sigma_d/\bar{x}_1$)	1,12	3,47		6,19	3,13		
	t — value	2,26	2,13	1,03	4,13	2,62	3,99	0,58
	Significance	between 1-5%	between 1-5%	not significant	< 0,1%	between 1-5%	< 0,1%	not significant
1975/76	Number of samples	←			41			→
	Means: Huletts RD ($\bar{x}_1$)	80,64	34,01	42,31	16,50	15,11	1,10	3,02
	SMRI ($\bar{x}_2$)	80,39	33,68	41,82	16,48	15,08	1,10	2,58
	Difference ($\bar{d}$)	0,25	0,33	0,49	0,02	0,03	0,00	0,44
	Standard deviation (σ_d)	2,31	0,96	1,19	0,67	0,37	0,06	1,20
	Coefficient of variation ($100\sigma_d/\bar{x}_1$)	2,87	2,82		4,06	2,45		
	t — value	0,70	2,21	2,64	0,18	0,49	0,26	2,35
	Significance	not significant	between 1-5%	between 1-5%	not significant	not significant	not significant	between 1-5%

Notes: For 40 degrees of freedom (number of data sets less variable being compared) the following cut-off values apply:

	Confidence limit		
	95	99	99,9
t — value	2,02	2,70	3,55