

# PRE-CURING: A METHOD OF INCREASING A-MASSECUITE EXHAUSTION

By A. D. ROBERTSON\*

*Hulett's Sugar Limited, Research and Development, Mount Edgecombe*

R. D. ARCHIBALD

*Hulett's Sugar Limited, Darnall*

W. R. VAN DUYKER

*Hulett's Sugar Limited, Felixton*

and R. G. HOEKSTRA

*Hulett's Sugar Limited, Operations Research, Mount Edgecombe*

## Abstract

A-massecuite exhaustion can be substantially improved by boiling very high brix strikes. The resultant extra crystal content would normally cause mechanical problems in the crystallisers and centrifuges. However, practical tests have shown that this excess crystal can be easily removed by curing part of the massecuite at strike, and returning the undiluted fraction of the molasses to the remainder of the massecuite in the crystalliser. This procedure is called pre-curing and allows the benefit of increased A-massecuite exhaustion to be enjoyed without adversely affecting product sugar quality or exceeding the permissible crystal content limits. A mathematical model has been constructed which calculates the advantages of increased A-exhaustion, which the practical tests have shown to be feasible.

## Introduction

The loss of sucrose in final molasses represents the largest loss to the miller and as a consequence, a great deal of attention is given to attaining the lowest possible final molasses purity. Expenditure on and improvements to equipment therefore tends to be concentrated on the C-station whereas front end exhaustion is given a low priority.

Julienne<sup>1</sup> showed in practical terms just how important A-exhaustion is to overall performance — until its recent closure, Melville led the Boiling House Recovery tables for 5 years. Theoretically too, increasing A-exhaustion has calculable advantages viz :

- less total massecuite boiled;
- less recycling of impurities;
- greater steam economy.

In times of high inflation, the costs of providing additional equipment to improve overall recovery become prohibitive and increasing A-exhaustion is a relatively inexpensive, effective way of increasing crystalliser residence times.

There are, however, limits to A exhaustion since, as the crystal content of massecuite increases, the viscosity of the massecuite becomes excessive leading to mechanical problems.

Increasing A-exhaustion is pointless if excess crystal content causes the following problems :

- the massecuite cannot be removed from the pan in a reasonable time;
- the crystalliser drives cannot handle the massecuite;
- the centrifugal baskets cannot be evenly loaded;
- excessive washing of the sugar is required leading to an inordinate purity rise across the centrifugals.

There are two well known methods of reducing excessive crystal content :

1. Boil slacker massecuites, which simply decreases exhaustion.
2. Lubricate the massecuite in the crystallisers with A-molasses — a technique known as backblending. This is schematically shown in Figure 1.

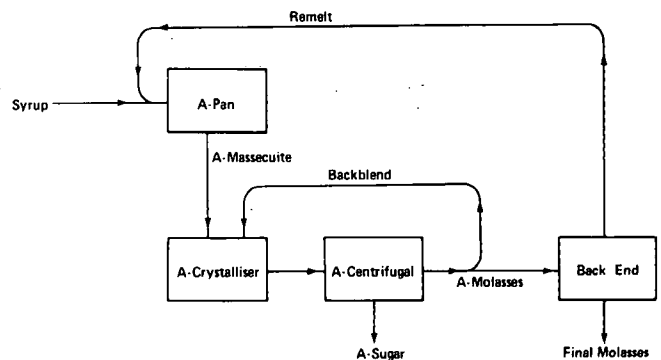


FIGURE 1 Schematic diagram of backblend operation.

The authors have over the past season examined the theoretical and practical aspects of a third method of reducing the crystal content of massecuites which is called pre-curing and has been used for some time now in European beet factories to improve low grade exhaustions.<sup>2, 3, 4</sup>

## Theory of pre-curing

Pre-curing simply means centrifuging a portion of the massecuite at strike and returning the undiluted "heavy" molasses fraction to the remainder of the massecuite in the crystalliser. This removes the excess crystal content at strike thus allowing the tightest possible massecuite to be struck from the pan without adversely affecting crystalliser and centrifugal operation. Figure 2 illustrates the process.

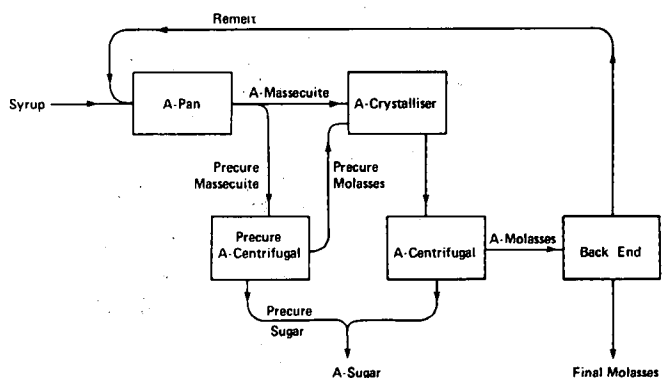


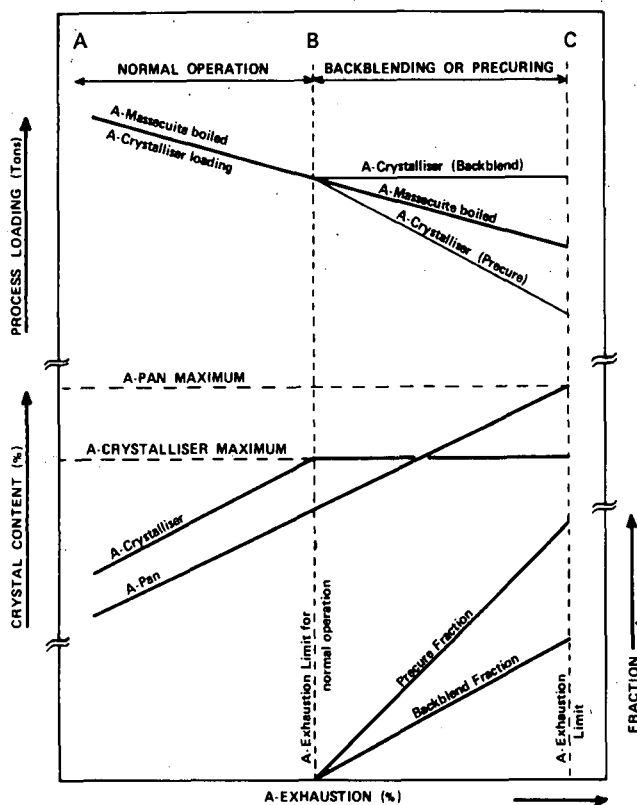
FIGURE 2 Schematic diagram of pre-cure operation.

\* Present address: Dwangwa Sugar Mill, Malawi.

Pre-curing has two main advantages over backblending :

- The returning mother liquor is at nearly the same saturation as the mother liquor at strike. Backblended molasses is less saturated since it has already been exhausted and, if unclassified, contains washing water which further reduces supersaturation.
- Less massecuite passes through the A-crystallisers thus increasing the effective residence time. This will tend to aid exhaustion.

Appendix 1 provides the material balance derivations of how some process variables of interest are affected by the extent of A-exhaustion. These relationships are illustrated in Figure 3, and can be calculated for given values of syrup, remelt and final molasses purities and certain other process relationships and constraints.



**FIGURE 3** How backblending or pre-curing can increase the maximum achievable A-exhaustions and their effect on process loadings.

As the A-masseccuite exhaustion increases from A to B for normal operation (without backblending or pre-curing), the amount of A-masseccuite boiled decreases and the A-pan and the A-crystalliser crystal contents increase. The limit to A-exhaustion under such operation is reached when the A-crystalliser crystal content reaches the maximum value that can be handled, and can only be increased beyond B by backblending or pre-curing. Figure 3 shows how the backblend fraction or, alternatively, the pre-cure fraction has to increase as a function of A-exhaustion, commensurate with keeping the A-crystalliser at its allowable maximum crystal content. In both cases the amount of A-masseccuite to be boiled will further decrease.

It is important to note that, with backblending, the A-crystalliser loading remains constant, independent of A-exhaustion, whereas with pre-curing, it decreases with increasing A-exhaustion.

The exhaustion can be increased up to point C, at which the A-pan crystal content will have reached the maximum which can be struck. Point C thus represents the maximum

possible exhaustion which can be achieved for a given set of conditions.

It should be noted that "A-exhaustion" on the horizontal axis refers to the overall exhaustion of the original A-masseccuite.

### Experimental

#### Exhaustion tests :

Experiments were conducted initially at Darnall and also at Felixton towards the end of the season. Boilings were carried out on ordinary A-pans and pre-cured by diverting the freshly struck massecuite for curing on the A-centrifugals.

Exhaustion of simulated pre-cured massecuite was carried out in a small self-contained water-jacketted pilot crystalliser holding  $\pm 70$  kg of massecuite stirred by paddles revolving at  $2/3$  rpm. The temperature of the massecuite was controlled by pumping  $\pm 10$  l/min of water at a set temperature through the jacket.

Masseccuites for pre-curing were boiled as tight as possible using a "Calcor" pan control system at Darnall and conductivity indication at Felixton. The massecuite was struck and a massecuite and a nutsch sample taken about half-way through striking. Striking times were longer than normal averaging 35 minutes. The massecuite was then diverted to the centrifugals, a known mass being taken meantime and placed in the pilot crystalliser pre-heated to strike temperature. Sufficient pre-cure molasses was easily obtained by cutting off the steam and water to one centrifugal and collecting the issuing molasses, a measured quantity of which was added to the pilot crystalliser.

No difficulty was experienced in mixing the massecuite with the pre-cure molasses. We aimed to add only sufficient pre-cure molasses to attain the normal crystal content at cure in the pilot crystalliser after the actual factory A-crystalliser residence time had elapsed.

A cooling profile similar to that observed in the factory A-crystallisers was followed. Nutsch samples were obtained by withdrawing a small quantity (1-2 kg) from the pilot crystalliser and centrifuging or vacuuming the mother liquor through A-centrifugal screen mesh.

Masseccuite and nutsches were analysed by vacuum oven drying and Lane and Eynon titration for true purity and for brix and pol apparent purity. The standard methods of analysis appearing in the SASTA Laboratory Manual for South African Sugar factories were used.

#### Centrifugal tests.

Pre-cure centrifugal operation in the real situation would aim to allow as much molasses to drain from the massecuite in the basket during the initial part of the high speed cycle so as to obtain the "heavy" or "spin" fraction for returning to the crystallisers as pre-cure molasses. Wash water and steam would then be applied to wash up the spun sugar to product sugar pol. A second "light", "washup" molasses fraction of low brix and high purity would thereby be obtained.

Testing was carried out using the following criteria :

- acceptable product sugar quality must be maintained.
- the total cycle duration must not be lengthened.
- two distinct fractions of molasses should be obtained.

Vapour and water application and cycle duration were adjusted on the switchgear timers.

Molasses was sampled at peak flows and sugars were sampled throughout plough out. Events were timed using a stopwatch. Steam and water flows at Felixton were mea-

**TABLE 1**  
Exhaustion data for pre-cure tests

Date	% Pre-cure	Exhaustion at strike		Exhaustion after Factory Crystalliser residence time		Factory Week Average Apparent exhaustion	Week Average—Test exhaustion at strike (Apparent)
		Apparent	True	Apparent	True		
<b>Darnall</b>							
29/8/78 . . .	31,5	70,5	66,4	75,4	70,1	65,6	4,9
1/9/78 . . .	31,5	67,3	70,9	75,5	74,2	65,6	1,7
5/9/78 . . .	25,0	73,1	69,3	76,2	69,9	64,8	8,3
15/9/78 . . .	Nil	63,6	59,4	69,7	64,5	64,8	- 1,2
21/9/78 . . .	24,0	70,2	66,0	72,3	68,8	64,4	5,8
28/9/78 . . .	21,5	69,3	64,3	72,2	67,0	63,6	5,7
<b>Felixton</b>							
20/12/78 . . .	26,7	73,1	67,8	73,2	63,8	67,2	5,9
10/ 1/79 . . .	29,5	67,5	64,9	68,6	66,6	66,9	0,6

sured during one of the tests by dismantling the feed pipes and diverting the flows. The values obtained were regarded as indicative rather than definitive, as water and especially vapour pressures fluctuate.

Sugar and molasses samples were composited from 3 or 4 consecutive cycles on each setting. The testing period was of approximately half hour duration at Darnall and 2 hours at Felixton. A brief check on the other machines at Darnall and Felixton indicated that the centrifugals used in testing were representative of the other A-centrifugals.

**Results**

*Exhaustion tests*

Results of the exhaustion tests appear in Table 1, whilst values from which they were derived appear in Appendix 2. Exhaustions at strike were high due to the tightness of the boilings. Exhaustions on an apparent purity basis averaged 70% at strike. A further increase in exhaustion was observed after crystallisation in the pilot crystalliser. At Felixton only two tests were carried out but the results are consistent with those obtained at Darnall. As a pessimistic rule of thumb, in the real factory situation any gains of exhaustion achieved in the pilot crystalliser would be lost across the centrifugals and therefore exhaustion at strike was compared with average factory A-exhaustion. On this basis, test boilings at strike beat week average factory exhaustions by about 5 units. (The exception to this was an ordinary boiling tested on 15.9.78 at Darnall.)

Examining the true exhaustion data (Table 1), shows that an average of 96% of the total exhaustion attained took place in the pan. This illustrates the vital importance of good pan work.

Because of mechanical constraints, no advantage could be gained from this extra exhaustion in the real situation unless backblending or pre-curing is carried out to reduce the masse-cuite crystal content at cure to the normal operating level.

Summarising the exhaustion tests :

- by boiling very tight masse-cuites, exhaustions at strike on an apparent purity basis of  $\pm 70\%$  have been achieved which compares very favourably with the season factory averages of 63-64%.
- the quantity of masse-cuite subsequently pre-cured will vary but 25-30% would normally be sufficient to reduce crystal content at cure to the average level.

*Centrifugal tests.*

Various pre-cure cycles were tried and compared with the normal cycle. In the latter, vapour was injected into the basket throughout the cycle and water was applied for a short period just after maximum rpm was attained. In pre-cure cycles, the water wash was applied later in the cycle and vapour injected either for the total cycle or from the start of water application until the end of the cycle. The pre-cure cycles gave the desired two easily separable molasses fractions.

**TABLE 2**  
Felixton A-centrifugal test data

	12/12/78			13/12/78			20/12/78			4/1/79			10/1/79	
	Normal cycle	Pre-cure cycle	No wash	Pre-cure cycle	Pre-cure cycle	No wash	Pre-cure cycle	Pre-cure cycle	No wash	Normal cycle	Pre-cure cycle	No wash	Pre-cure cycle	No wash
<i>Time of event (seconds):</i>														
Loading finished . . . . .	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Steam On . . . . .	0	87	-	0	88	-	0	101	-	0	0	-	70	-
Off . . . . .	138	142	-	145	145	-	142	135	-	163	138	-	115*	-
Water On . . . . .	60,5	74	-	88	88	-	86	80	-	64	60	-	70	-
Off . . . . .	72	87	-	102	101	-	103	93	-	75	70	-	85	-
1500 rpm From . . . . .	60	62	60	61	60	60	68	60	61	59	60	60	60	60
To . . . . .	107	109	96	107	107	87	112	101	80	130	105	77	115	85
Total cycle time . . . . .	210	214	198	210	211	190	215	210	190	238	213	185	215	195
<i>Product parameters:</i>														
Spin molasses: True purity . . . . .	-	-	-	70,3	70,6	70,5	70,1	69,1	69,1	-	67,5	67,5	64,5	64,5
Wash molasses: True purity . . . . .	-	-	-	84,4	82,1	-	84,5	82,9	-	-	75,2	-	88,8	-
Sugar purity . . . . .	99,17	99,23	98,83	99,48	99,37	98,52	99,39	99,43	98,69	99,39	99,42	98,44	99,24	98,16

\* Vapour flow supplemented to give 7,4 kg/min instead of normal 2,6 kg/min.

At Darnall tests were of short duration due to production pressure but established that the pre-cure sugar would meet specification. Testing at Felixton was carried out both on normal and pre-cure massecuites at strike. The results of the Felixton A-centrifugal tests are summarised in Table 2. A typical cycle is illustrated in Figure 4.

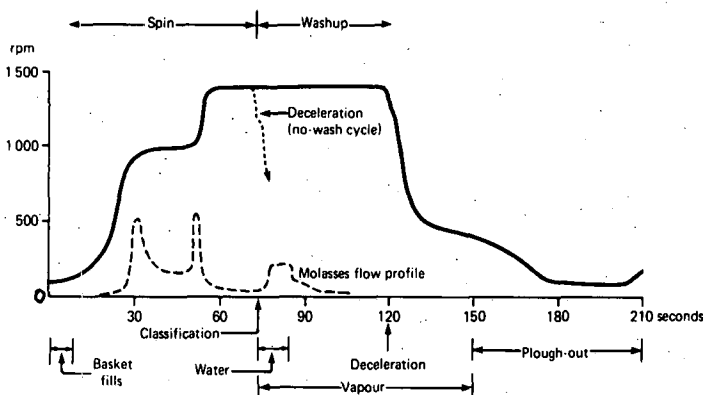


FIGURE 4 Schematic diagram of a pre-cure centrifugal cycle at Felixton.

Wash water and vapour flows were measured at Felixton and found to be 36 kg/min and 2,6 kg/min respectively. The latter seemed to be a very low figure and the flow on 10.1.79 was supplemented giving an extra 4,6 kg/min of vapour.

Judging by the resultant purity of the washup molasses in this case (88,8% compared with 82-84%), steam is a washing agent to be applied with caution. In some cases (e.g. 12.12.78) sugar quality for both normal and pre-cure cycles was below specification (99,4 purity) but overall there is no indication that pre-cure sugar would be substandard in any way, or that the cycle time needs to be lengthened. On 4.1.79 for instance, it was possible to shorten the cycle without affecting sugar quality.

Using figures from the tests, the average solids quantity of washup molasses which would be produced by pre-curing 30% of the massecuite was calculated by the SJM formula, using the purities of the "no-wash" sugar, normal specification raw sugar and the washup molasses for each cycle.

It is estimated that the mass of solids in washup molasses would be less than 3% of the product sugar mass (See Appendix 3). This fraction could either be added to the A-molasses or preferably to the remelt.

Summarising the results of centrifugal testing :

- Pre-cure sugar quality is not a problem.
- No increase in centrifugal cycle time is required.
- Distinct fractions of molasses are easily obtained.

### Conclusions

Our tests have shown that it is possible to increase substantially A-massecuite exhaustion by boiling very tight strikes. This would normally cause mechanical problems but the resultant excessive crystal content can be removed by immediately curing about 30% of the massecuite and returning the "heavy" fraction of the molasses to the remaining massecuite in the crystallisers.

There is no evidence to suggest that product sugar quality would be adversely affected.

Pre-curing appears to be a viable and effective means of increasing A-massecuite exhaustion and reducing overall factory massecuite quantities.

### Acknowledgements

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### Glossary of terms

- brix — refractometer solids
- heavy — high brix (molasses)
- light — low brix (molasses)
- nutsch — mother liquor
- slack — low brix (massecuite)
- spin — part of a centrifugal cycle where no washing is applied.
- strike — removal of massecuite from a pan.
- tight — high brix (massecuite).
- vapour — saturated low pressure steam
- washup — part of a centrifugal cycle where wash water and vapour are applied.

### REFERENCES

1. Julienne, L. M. S. A. (1976). A-massecuite exhaustion and low purity C-massecuite at Melville. SASTA Proc 50, 194-7.
2. Genotelle, J. (1973). Malaxage des bas produits en sucrerie. Ind. Alimente. Agric. (90) p.953.
3. Wagnerowski, K. (1974). Wstępne wirowanie cukrzycy III jako źródło zwiększonej wydajności i wyższej jakości cukru. Gaz Cukrov (92) p.25.
4. Amding, F. (1976). Split separation of crystals with low grade massecuite trials in the 1975 campaign. Zucker (29) p.317.

### APPENDIX 1

#### Derivation of relationships for A-massecuite operations with back-blending or pre-curing

##### 1. Notation

Variables:

- B = mass total solids (i.e. mass true Brix).
- S = mass Sucrose.
- X = mass sucrose crystal (X-tal).
- P = Purity, as a fraction
- R = Recovery, (mass sucrose recovered)/(mass sucrose in starting material), as a fraction.
- C = Crystal Content, (mass sucrose crystal / mass total solids), as a fraction.
- E = Exhaustion, as a fraction — See Section 3.
- F = Fraction, by mass, that back-blend or pre-cure stream is of the A-massecuite.
- G = crystal Growth factor — See Section 3.

Note that, for convenience, purities, recoveries, crystal contents and exhaustions are given in fractions instead of the usual percentages, so as to avoid the occurrence of 100, 10 000, etc. in the mathematical derivations.

Subscripts:

- ACnt = A-Centrifugal
- ACr = A-Crystalliser
- AMol = A-Molasses
- AMsc = A-Massecuite
- APAN = A-Pan
- ASug = A-Sugar
- BBL = Backblend
- FMol = Final Molasses
- PF = Pan Floor
- PrC = Pre-Cure
- Rem = Remelt
- Syr = Syrup

Superscripts:

- \* = Maximum allowable for the variable.
- ° = Refers to the pre-cure portion of the A-massecuite.

The meaning of some of these sub and superscripts should become clearer further on.

2. Graphical representation

For illustration, some of the relationships which are to follow, will be calculated for different values of A-masseccite exhaustion  $E_{AMsc}$  and plotted in Fig. 5, using assumed values of the process parameters:

- Syrup, mass total solids . . . . .  $B_{Syr} = 100$  tons
- Purity of A-Sugar . . . . .  $P_{ASug} = 0,995 = 99,5\%$
- Purity of pre-cure A-Sugar . . . . .  $P^o_{ASug} = 0,995 = 99,5\%$
- Purity of Syrup . . . . .  $P_{Syr} = 0,89 = 89\%$
- Purity of Final Molasses . . . . .  $P_{FMol} = 0,42 = 42\%$
- Purity of Remelt . . . . .  $P_{Rem} = 0,90 = 90\%$
- Maximum Crystal Content for A-Pan  $C^*_{APan} = 0,60 = 60\%$
- Maximum Crystal Content for A-Crystallisers . . . . .  $C^*_{ACr} = 0,56 = 56\%$
- Crystal Growth factor in A-Crystallisers . . . . .  $G_{ACr} = 1,05$
- Sucrose crystal Recovery in A-Centrifugals . . . . .  $R_{ACnt} = 0,95 = 95\%$
- Sucrose crystal Recovery in pre-cure A-centrifugals . . . . .  $R^o_{ACnt} = 0,95 = 95\%$

To make the graph easier to read, the fractional values of exhaustion and crystal content will be converted into percentages.

3. General relationships — All cases

By Deerr's SJM formula, the mass of sucrose in A-sugar can be expressed as

$$S_{ASug} = \frac{P_{ASug} (P_{Syr} - P_{FMol})}{P_{Syr} (P_{ASug} - P_{FMol})} S_{Syr}$$

Let  $R_{PF} = \frac{P_{ASug} (P_{Syr} - P_{FMol})}{P_{Syr} (P_{ASug} - P_{FMol})}$   
 = Pan Floor Recovery.

From this and the definition of purity:

$$S_{ASug} = B_{Syr} P_{Syr} R_{PF} \dots \dots \dots (1)$$

Crystal Content at discharge from A-pan

$$C_{APan} = \frac{\text{Mass sucrose crystals in A-pan at discharge}}{\text{Mass total solids in A-pan}}$$

$$= \frac{X_{APan}}{B_{AMsc}}$$

Re-arranging,

$$X_{APan} = B_{AMsc} C_{APan} \dots \dots \dots (2)$$

Define crystal Growth factor in A-crystalliser as

$$G_{ACr} = \frac{\text{Mass sucrose crystals in A-crystalliser before centrifuging}}{\text{Mass sucrose crystals in A-pan at discharge}}$$

$$= \frac{X_{ACr}}{X_{APan}}$$

Substituting for  $X_{APan}$  from (2) and re-arranging:

$$X_{ACr} = B_{AMsc} C_{APan} G_{ACr} \dots \dots \dots (3)$$

Define crystal Recovery during A-masseccite centrifuging as

$$R_{ACnt} = \frac{\text{Mass sucrose recovered as A-sugar after centrifuging}}{\text{Mass sucrose in crystals in A-crystalliser before centrifuging}}$$

$$= \frac{S_{ASug}}{X_{ACr}}$$

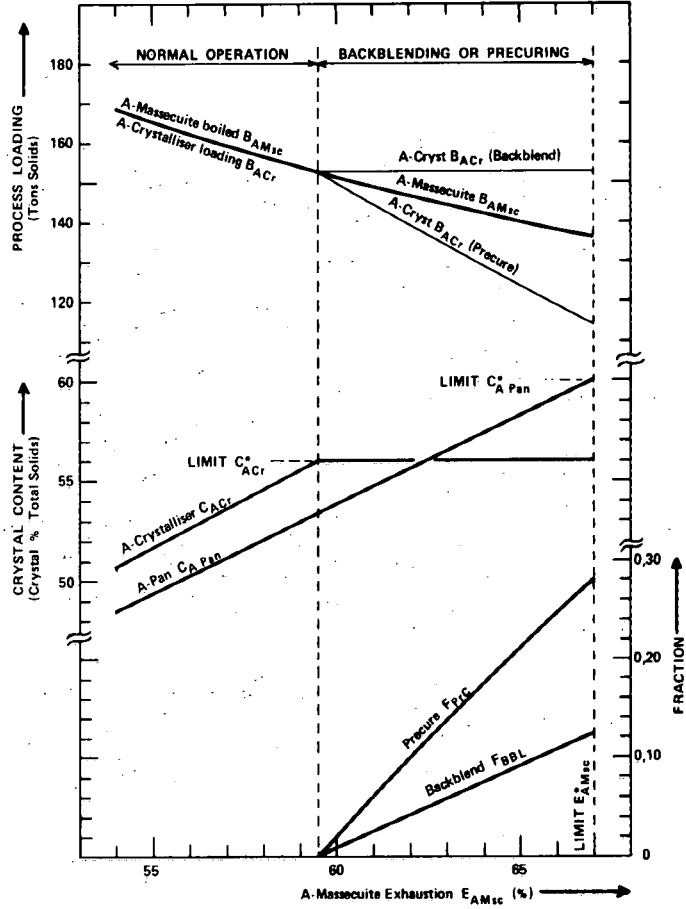


FIGURE 5 Graphical representation of numerical example from Appendix I.

Substituting for  $S_{ASug}$  from (1) and for  $X_{ACr}$  from (3), and re-arranging:

$$B_{AMsc} = B_{Syr} P_{Syr} R_{PF} / (C_{APan} G_{ACr} R_{ACnt}) \dots \dots \dots (4)$$

A-masseccite = Syrup feed + Remelt

i.e.  $B_{Rem} = B_{AMsc} - B_{Syr} \dots \dots \dots (5)$

$$S_{AMsc} = S_{Rem} + S_{Syr}$$

Using definition of purity, substituting for  $B_{Rem}$  from (5) and re-arranging:

$$= B_{AMsc} P_{Rem} - B_{Syr} (P_{Rem} - P_{Syr}) \dots \dots \dots (6)$$

For convenience in derivation, the usual definition of

$$\text{A-msc. Exhaustion} = \frac{1}{P_{AMsc}} \left[ \frac{P_{AMsc} - P_{AMol}}{1 - P_{AMol}} \right]$$

(using fractions instead of percentages)

is not used, which in any case gives a false indication of sucrose recovery when the A-sugar product is not 100% pure.

Instead, define

$$E_{AMsc} = \frac{P_{ASug} [P_{AMsc} - P_{AMol}]}{P_{AMsc} [P_{ASug} - P_{AMol}]} = \frac{S_{ASug}}{S_{AMsc}}, \text{ by SJM formula.}$$

Substituting for  $S_{ASug}$  from (1) and for  $S_{AMsc}$  from (6):

$$E_{AMsc} = \frac{B_{Syr} P_{Syr} R_{PF}}{B_{AMsc} P_{Rem} - B_{Syr} (P_{Rem} - P_{Syr})}$$

Re-arranging,

$$B_{AMsc} = \frac{B_{Syr} \left[ \frac{R_{PF} P_{Syr}}{E_{AMsc}} + (P_{Rem} - P_{Syr}) \right]}{P_{Rem}} \dots \dots \dots (8)$$

Substituting for  $B_{AMsc}$  from (8) into (5):

$$B_{Rem} = \frac{B_{Syr} \left[ \frac{R_{PF} P_{Syr}}{E_{AMsc}} - P_{Syr} \right]}{P_{Rem}} \dots \dots \dots (9)$$

From (8) and (9) it is clear that, the higher the A-massecuite exhaustion  $E_{AMsc}$ , the lower are the amounts of A-massecuite  $B_{AMsc}$  and remelt  $B_{Rem}$  to handle.

Substituting for  $B_{AMsc}$  from (4) into (7):

$$E_{AMsc} = \frac{P_{Syr} R_{PF}}{P_{Rem} P_{Syr} R_{PF} / (C_{APan} G_{ACr} R_{ACnt}) - (P_{Rem} - P_{Syr})} \dots \dots \dots (10)$$

Re-arranging,

$$C_{APan} = \frac{P_{Rem}}{G_{ACr} R_{ACnt} [1/E_{AMsc} + (P_{Rem} - P_{Syr}) / (P_{Syr} R_{PF})]} \dots \dots \dots (11)$$

This quantifies the intuitively obvious, that increased exhaustion  $E_{AMsc}$  increases the A-pan crystal content  $C_{APan}$ .

4. Usual operation — No backblending or pre-curing

Crystal content of A-crystalliser before centrifuging

$$C_{ACr} = \frac{\text{Mass sucrose crystals in A-crystalliser}}{\text{Mass total solids in A-crystalliser}} = \frac{X_{ACr}}{B_{AMsc}}$$

Substituting for  $X_{ACr}$  from (3) and then for  $C_{APan}$  from (11):

$$= \frac{P_{Rem}}{R_{ACnt} [1/E_{AMsc} + (P_{Rem} - P_{Syr}) / (P_{Syr} R_{PF})]} \dots \dots \dots (12)$$

The total solids mass loading on the A-crystallisers is simply the A-massecuite, i.e.

$$B_{ACr} = B_{AMsc}$$

Substituting from (8):

$$= \frac{B_{Syr} \left[ \frac{R_{PF} P_{Syr}}{E_{AMsc}} \pm (P_{Rem} - P_{Syr}) \right]}{P_{Rem}} \dots \dots \dots (13)$$

The left portion of Fig. 5 shows how the A-massecuite exhaustion  $E_{AMsc}$  influences the A-pan crystal content  $C_{APan}$ ; the A-crystalliser crystal content  $C_{ACr}$ ; the total solids mass A-massecuite boiled  $B_{AMsc}$  and A-crystalliser loading  $B_{ACr}$ , using equations (11), (12), (8) and (13) respectively.

The A-crystalliser and its following A-centrifugal operation can only deal with up to a certain maximum crystal content  $C^*_{ACr}$ , and this, when substituted into (12) will, upon re-arranging, express the limit to which A-massecuite exhaustion  $E_{AMsc}$  can be taken without backblending or pre-curing.

5. Backblending

Let  $B_{BBL}$  = Mass total solids in backblend stream;

$F_{BBL}$  = Mass backblend as fraction of A-massecuite =  $B_{BBL} / B_{AMsc}$

Mass total solids in A-crystalliser = Original massecuite + backblend;

i.e.  $B_{ACr} = B_{AMsc} (1 + F_{BBL}) \dots \dots \dots (14)$

Assume that the A-crystallisers are operated at their maximum crystal content:

$$C^*_{ACr} = \frac{\text{Max. possible mass sucrose crystals in A-crystalliser}}{\text{Mass total solids}} = \frac{X_{ACr}}{B_{AMsc} (1 + F_{BBL})}$$

Substituting for  $X_{ACr}$  from (3) and re-arranging:

$$C_{APan} = C^*_{ACr} (1 + F_{BBL}) / G_{ACr} \dots \dots \dots (15)$$

Substituting into (11) to eliminate  $C_{APan}$  and re-arranging:

$$F_{BBL} = \frac{P_{Rem} - 1}{C^*_{ACr} G_{ACr} R_{ACnt} [1/E_{AMsc} + (P_{Rem} - P_{Syr}) / (P_{Syr} R_{PF})]} \dots \dots \dots (16)$$

It can be seen from (16) that, as the A-massecuite exhaustion  $E_{AMsc}$  is increased, the minimum backblend fraction  $F_{BBL}$  needed to prevent the A-crystalliser crystal content  $C_{ACr}$  from exceeding the maximum  $C^*_{ACr}$ , has to be increased.

Substituting for  $B_{AMsc}$  from (4) and for  $F_{BBL}$  from (16) into (14):

$$B_{ACr} = B_{Syr} P_{Syr} R_{PF} / (C^*_{ACr} R_{ACnt}) \dots \dots \dots (17)$$

From (17) can be seen that with backblending, the loading on the A-crystalliser  $B_{ACr}$  is independent of the backblend fraction  $F_{BBL}$  or the A-massecuite exhaustion  $E_{AMsc}$ , but is inversely proportional to the maximum allowable crystal content  $C^*_{ACr}$ .

The right-hand side of Fig. 5 shows how the A-pan crystal content  $C_{APan}$ ; the backblend fraction  $F_{BBL}$ ; the total solids mass A-massecuite boiled  $B_{AMsc}$  and A-crystalliser loading  $B_{ACr}$  are affected by the A-massecuite exhaustion  $E_{AMsc}$ , using equations (11), (16), (8) and (17).

By sufficiently increasing the backblending fraction  $F_{BBL}$  so as not to exceed the permissible A-crystalliser crystal content  $C^*_{ACr}$ , the A-massecuite exhaustion  $E_{AMsc}$  can be increased to a maximum  $E^*_{AMsc}$ , at which the A-pan crystal content  $C_{APan}$  reaches its allowable maximum of  $C^*_{APan}$ , and can be calculated from (10).

6. Pre-curing

Let  $B^{\circ}_{AMsc}$  = A-massecuite diverted (by total solids mass) to pre-cure from the entire A-massecuite  $B_{AMsc}$ ;

$F_{PrC}$  = Fraction of A-massecuite and hence fraction of A-pan crystal content diverted for pre-cure

$$= \frac{B^{\circ}_{AMsc}}{B_{AMsc}} = \frac{X^{\circ}_{APan}}{X_{APan}} \dots \dots \dots (18)$$

Mass sucrose in pre-cure sugar, by definition of  $R^{\circ}_{ACnt}$ , is

$$S^{\circ}_{ASug} = X^{\circ}_{APan} R^{\circ}_{ACnt}$$

Substituting for  $X^{\circ}_{APan}$  from (18) and then for  $X_{APan}$  from (2):

$$= B_{AMsc} C_{APan} F_{PrC} R^{\circ}_{ACnt} \dots \dots \dots (19)$$

Dividing (19) by  $P^{\circ}_{ASug}$ :

Total solids mass in pre-cure sugar

$$B^{\circ}_{ASug} = B_{AMsc} C_{APan} F_{PrC} R^{\circ}_{ACnt} / P^{\circ}_{ASug} \dots \dots \dots (20)$$

Mass sucrose crystals in A-crystalliser = (Mass crystals in A-pan) × (Crystal growth factor) — Sucrose removed in pre-cure

$$X_{ACr} = X_{APan} G_{ACr} - S^{\circ}_{ASug}$$

Substituting for  $X_{APan}$  from (3) and for  $S^{\circ}_{ASug}$  from (19):

$$= B_{AMsc} C_{APan} G_{ACr} (1 - F_{PrC} R^{\circ}_{ACnt} / G_{ACr}) \dots \dots \dots (21)$$

Total solids mass in A-crystalliser

$$B_{ACr} = B_{AMsc} - B^{\circ}_{ASug}$$

Substituting for  $B^{\circ}_{ASug}$  from (20):

$$= B_{AMsc} C_{APan} \left[ \frac{1}{C_{APan}} - \frac{F_{PrC} R^{\circ}_{ACnt}}{P^{\circ}_{ASug}} \right] \dots \dots \dots (22)$$

Assume that the A-crystallisers are operated at their maximum crystal content:

$$C^*_{ACr} = X_{ACr}/B_{ACr}, \text{ by definition of } C_{ACr}.$$

Substituting for  $X_{ACr}$  from (21) and for  $B_{ACr}$  from (22), and re-arranging:

$$\frac{1}{C_{APan}} = \frac{G_{ACr}}{C^*_{ACr}} \left[ 1 - \frac{F_{PrC} R^{\circ}_{ACnt}}{G_{ACr}} \left( 1 - \frac{C^*_{ACr}}{P^{\circ}_{ASug}} \right) \right] \dots \dots \dots (23)$$

Substituting into (11) and re-arranging:

$$F_{PrC} = \frac{G_{ACr}}{R^{\circ}_{ACnt} (1 - C^*_{ACr}/P^{\circ}_{ASug})} \left[ 1 - \frac{C^*_{ACr} R_{ACnt}}{P_{Rem}} \left( \frac{1}{E_{AMsc}} + \frac{P_{Rem} - P_{Syr}}{P_{Syr} R_{PF}} \right) \right] \dots \dots \dots (24)$$

From (24) can be seen that, as the A-massecuite exhaustion  $E_{AMsc}$  increases, the necessary pre-cure fraction  $F_{PrC}$  to keep the A-crystalliser crystal content at its allowable maximum  $C_{ACr}$ , has to be increased.

Substituting for  $B_{AMsc}$  from (4) and then for  $1/C_{APan}$  from (23) into (22), and simplifying:

Total solids mass in A-crystallisers

$$B_{ACr} = \frac{B_{Syr} P_{Syr} P_{PF}}{C^*_{ACr} R_{ACnt}} \left[ 1 - F_{PrC} \frac{R^{\circ}_{ACnt}}{G_{ACr}} \right] \dots \dots \dots (25)$$

From (25) can be seen that the crystalliser total solids mass loading  $B_{ACr}$  decreases with increase in pre-cure fraction  $F_{PrC}$ .

By sufficiently increasing the pre-cure fraction  $F_{PrC}$ , the maximum achievable A-massecuite exhaustion  $E^*_{AMsc}$  will be reached when the A-pan crystal content reaches its maximum allowable value of  $C^*_{APan}$ .

The right-hand side of Fig. 5 shows how the A-pan crystal content  $C_{APan}$ ; the pre-cure fraction  $F_{PrC}$ ; the total solids mass A-massecuite boiled  $B_{AMsc}$  and A-crystalliser loading  $B_{ACr}$  are affected by the A-massecuite exhaustion  $E_{AMsc}$ , using equations (11), (24), (8) and (25).

The advantages of backblending or pre-curing over normal operation for reducing the amount of A-massecuite boiled, and of pre-curing over backblending for reducing the A-centrifugal loading, can clearly be seen.

### APPENDIX 3

#### Calculations

Formulae used to calculate massecuite exhaustions (Table 1) and massecuite crystal contents (Appendix 2):

$$\text{Exhaustion} = 10\,000 \cdot \frac{(\text{purity massecuite} - \text{purity molasses})}{(\text{purity massecuite} (100 - \text{purity molasses}))}$$

$$\text{Crystal content} = 100 \times \text{massecuite solids} \cdot \frac{(\text{purity massecuite} - \text{purity molasses})}{(100 - \text{purity molasses})}$$

Example of calculation of washup molasses solids quantity:

Take for instance, data from Table 2 for 13/12/78 —

Purity no-wash sugar	98,52
Purity 1st pre-cure cycle sugar	99,48
Purity washup molasses	84,4

Applying the SJM formula:

$$\begin{aligned} \text{Tons brix washup molasses} &= \text{tons brix product pre-cure sugar} \\ &\times \frac{98,48 - 99,52}{98,52 - 84,4} \\ &= 0,068 \times \text{tons brix product pre-cure sugar.} \end{aligned}$$

$$\begin{aligned} \text{Assuming 30\% of massecuite is pre-cured} & \\ &= 0,068 \times 0,3 \times \text{tons brix total product sugar} \\ &= 2,04\% \text{ tons brix total product sugar.} \end{aligned}$$

See page 56 for Appendix 2.

**APENDIX 2**  
**Data from exhaustion tests**

	% Pre-cure	Temperature °C	True purity	Apparent purity	Masseccuite crystal content	Masseccuite calculated crystal content without pre-curing
<u>Darnall</u>						
<u>29.8.78</u>						
94,31% solids masseccuite		70	86,6	86,8	-	-
Nutsch at strike		70	68,5	66,1	54,3	-
Pre-cured masseccuite	31,5	68	84,4	-	46,1	54,3
Nutsch after 6 hrs*		62	66,0	61,9	50,2	57,4
A-molasses week ave.		-	-	72,3	-	-
<u>1.9.78</u>						
94,25% solids masseccuite		66	88,9	87,9	-	-
Nutsch at strike		66	70,0	69,4	59,4	-
Pre-cured masseccuite	31,5	66	86,3	-	50,2	59,4
Nutsch after 6 hrs*		60	67,4	64,0	53,5	62,2
A-molasses week ave.		-	-	72,3	-	-
<u>5.9.78</u>						
92,82% solids masseccuite		70	89,8	90,0	-	-
Nutsch at strike		70	72,9	70,8	57,5	-
Pre-cured masseccuite	25,0	66	87,0	-	50,7	57,7
Nutsch after 6 hrs*		60	72,5	68,2	51,4	58,2
A-molasses week ave.		-	-	74,1	-	-
<u>15.9.78</u>						
92,32% solids masseccuite		68	88,0	88,3	-	-
Nutsch at strike		68	74,8	73,5	48,2	-
Pre-cured masseccuite		-	-	-	-	-
Nutsch after 6 hrs*	0	60	72,2	69,7	52,4	-
A-molasses week ave.		-	-	74,4	-	-
<u>21.9.78</u>						
93,06% solids masseccuite		68	88,6	89,0	-	-
Nutsch at strike		68	72,5	70,7	54,4	-
Pre-cured masseccuite	24,0	68	87,3	-	49,1	54,4
Nutsch after 6 hrs*		60	72,8	69,1	51,9	56,7
A-molasses week ave.		-	-	75,0	-	-
<u>28.9.78</u>						
93,28% solids masseccuite		68	88,0	88,7	-	-
Nutsch at strike		68	72,1	79,7	53,2	-
Pre-cured masseccuite	21,5	68	86,7	-	46,9	53,2
Nutsch after 6 hrs*		62	70,8	68,7	50,1	55,0
A-molasses week ave.		-	-	74,0	-	-
<u>Felixton</u>						
<u>20.12.78</u>						
92,74% solids masseccuite		64	87,8	88,3	-	-
Nutsch at strike		64	69,8	67,0	55,3	-
Pre-cured masseccuite	26,7	64	85,5	-	47,5	55,3
Nutsch after 3 hrs*		64	68,5	66,9	48,4	56,8
A-molasses week ave.		-	-	69,6	-	-
<u>10.1.79</u>						
92,83% solids masseccuite		62	84,6	84,1	-	-
Nutsch at strike		62	65,9	63,2	51,0	-
Pre-cured masseccuite	25,5	62	82,0	-	43,6	51,0
Nutsch after 3 hrs*		62	64,8	62,4	44,7	52,3
A-molasses week ave.		-	-	68,5	-	-

\* Actual factory A-crystalliser residence time