

THE DEVELOPMENT OF A MASS, ENERGY AND COLOUR BALANCE MODEL FOR A RAW SUGAR FACTORY AND ITS USE TO PREDICT THE EFFECTS OF ELIMINATING A- AND B-CRYSTALLISERS AND INTRODUCING BACK BOILING

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Abstract

A computer spreadsheet model of a raw sugar factory which includes mass, energy, and colour balances, and a pan crystallisation model have been developed. The model can predict the colour of sugars and of various other process streams. Good agreement was obtained between colours predicted by the model and those measured in raw sugar factories. Results from the model predicting the effects on raw sugar colour for variations in operating conditions are given. The effects of eliminating A- and B-crystallisers coupled with the introduction of back boiling were also investigated. It was predicted that raw sugar colour will not be significantly changed and similar or higher overall exhaustions should be attainable. Decomposition losses should also be reduced. A disadvantage is that higher pan capacities and more process steam will be required.

Keywords: Colour, model, crystallisers, back boiling.

Introduction

The installation of A- and B-crystallisers has become an established practice in South African sugar factories. Generally residence times are about 10-12 hours for A-masseccutes and 12-24 hours for B-masseccutes.

Julienne (1991) has questioned the justification for B-crystallisers and concluded that installation of these in a new factory was unjustified since they contributed little if anything to overall recovery. An increase in B-molasses purity would not normally result in an increase in C-masseccute purity since the quantity of A-molasses and/or syrup used for seed preparation could be reduced. The advantages of not having B-crystallisers included saving in capital, reduction in losses by degradation, and reduction in required B-centrifugal capacity. The disadvantages included a small increase in steam consumption and it was concluded that the advantages far outweighed the disadvantages. Following the publishing of the paper, B-crystallisers were taken out of service at Malelane without any apparent reduction in overall recovery, and the new Komati raw sugar factory was designed without B-crystallisers.

In a later paper Julienne (1992) compared A- and B-pans and crystallisers in terms of cost and concluded that crystallisers compared poorly in terms of crystallisation rates and cost. He suggested that installation of crystallisers to achieve increased exhaustions in A- and B-masseccutes may be unjustified.

The maximisation of exhaustion of A-masseccutes and to a lesser extent B-masseccutes is highly desirable because it has a large influence on the quantity of masseccutes boiled. It is firmly believed by many process personnel that a high A- and

B-masseccute exhaustion is the key to achieving high boiling house recoveries.

A practical factor favouring having a low B-molasses purity is that it enables more A-molasses and/or syrup to be used in the earlier stages of the boiling of C-masseccutes. This allows a good grain with a higher crystal content to be established prior to feeding B-molasses which ultimately leads to higher pan exhaustion and a reduction in losses over the centrifugals.

In this paper, it is proposed that A- and B-crystallisers are not necessary, and that similar or greater exhaustions can be achieved in the pan by back boiling molasses from the centrifugals without incurring increases in sucrose degradation or sugar colour.

Pan crystallisation model

In order to evaluate the effects of back boiling and colour transfer during pan boiling, a pan crystallisation model was set up on a spreadsheet and combined with an overall factory mass and energy balance model. This model simulated a three boiling system as used in the South African sugar industry.

To simplify the crystallisation model, the A-, B-, and C-stations were considered to consist of discreet stages in series where constant boiling conditions were maintained in each stage similar to a factory using continuous pans.

In the B-station, preparation of B-seed was assumed as one stage where crystal content and crystal width were defined. This was then followed by 12 stages to simulate the B-boiling system. A thirteenth stage represented the crystallisers. In each of the 12 stages, evaporation rate, masseccute brix, and crystal content were entered, and crystal size, mother liquor brix, and purity calculated.

A-molasses purity and colour used in the B-model were derived from an A-boiling model.

The A-station was simulated in a similar way where preparation of A-seed was assumed to be one stage followed by 13 further stages. B-magma flow, B-sugar purity, and B-sugar pol were user defined and colour of B-sugar was calculated in the model. The model was extended to include C-boilings as well.

Facilities were introduced to allow the model to be used for the evaluation of back boiling on A- and B-masseccutes. This consisted of allowing the last one or two stages to be fed with molasses from the centrifugals after dilution in the blow-up tanks. Crystal and sugar colours in the model were calculated as described below.

Colour transfer during crystallisation

From boilings carried out in a laboratory pan Lionnet (1988) derived equations relating colour transfer to feed col-

our and crystal width, for two different crystallisation rates. Linear relationships between average colour transfer and crystal width were derived and these are given below:

Medium crystallisation rate:

$$\text{Colour transfer} = 0,00810 + 3,810 \times 10E-5.W$$

High crystallisation rate:

$$\text{Colour transfer} = 0,0132 + 3,590 \times 10E-5.W$$

where colour transfer = fraction of liquor feed colour in crystal

W = crystal width μm

The above relationships calculate sugar colour relative to feed liquor colour. In modeling a sugar factory, where magma is used for footing, and where different feed liquors are used during the boiling (e.g. seed preparation or back boiling), a means for calculating the crystal shell colour relative to mother liquor colour is required.

During the boiling of massecuites, most of the colour remains in the mother liquor and therefore mother liquor colour increases as crystal content increases.

It was assumed that, at any point during the crystallisation process, colour of sugar deposited is proportional to the mother liquor colour (i.e. constant colour transfer).

In order to test if this was a reasonable assumption, a separate model was set up to simulate a batch boiling where seeding is done on syrup. In this model crystal colours were calculated at various stages through the boiling using the relationships derived by Lionnet. Shell colours and mother liquor colours were then calculated as a function of crystal size using mass and colour balances, and the colour transfer coefficients were calculated. The results are shown in Figure 1.

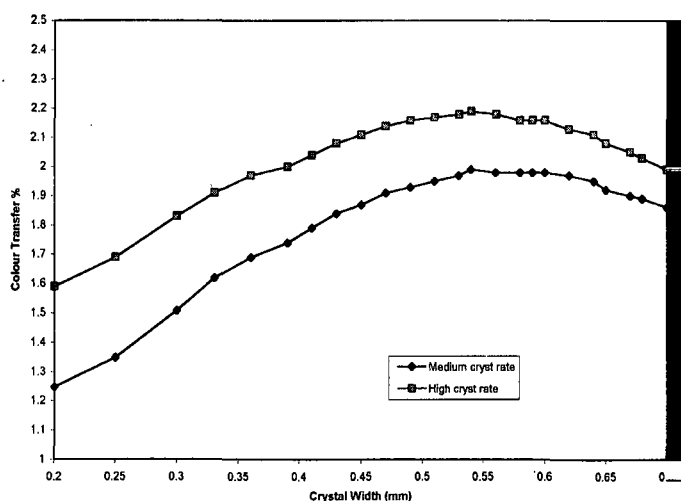


FIGURE 1: Colour transfer predicted by Lionnet

Over the range of 0,4 mm to 0,65 mm crystal width, a constant colour transfer appeared a reasonable approximation. Considering that about 80% of crystal mass is deposited over this size range, the assumption of a constant colour transfer over the whole boiling should still give a reasonable prediction of affinated A-sugar colour.

This was then used to calculate sugar colour deposited in each stage of boiling and average crystal colour was calculated by integration.

Sugar colour

The colours of A-, B-, and C-sugar were calculated from the crystal colour and mother liquor colour.

It was assumed that the sugar crystal purity (affinated) was 99,8 for A-sugar and 99,7 for B- and C-sugar. From the sugar purity and purity of mother liquor in the last stage of boiling (or from the crystallisers), the quantity of molasses relative to affinated crystal was calculated. The sugar colour was then calculated from the crystal and mother liquor colours.

As a base case the model was set up to simulate a three boiling system where some B-sugar was used for A-footing and surplus B- and all C-sugar were melted and combined with syrup.

Facilities were provided in the model to allow for colour formation in the A-, B- and C- stations. These were user defined.

Getaz and Bachan (1989) measured colours at UK, IL and DL, at various points through the process. The model was set up to try to simulate the average colours from these three factories.

In setting up the model the following assumptions were made:

- Colour of syrup from evaporators was 20 000 ICUMSA units and purity was 84,3;
- One part of B-magma was used as footing to produce 12 parts of A-masseccuite;
- A-exhaustion of 66, B-exhaustion of 61, and C-exhaustion of 54 were assumed;
- A drop of 2,4 units in nutch purity over both A- and B-crystallises was assumed;
- A purity rise of two units over A- and B-centrifugals, and three units over the C- centrifugals was assumed;
- A constant colour transfer was used for all boilings. The colour transfer and colour formations in the A- B- and C-stations were adjusted to fit the model to the measured data;
- A-sugar pol of 99,3 and B- and C-sugar purities of 92 and 83 were assumed.

A colour transfer of 1,5% was fitted. This was lower than measured by Lionnet.

Colour formations of 8% on A's, 15% on B's, and 25% on C's were used in the model. This gave a total colour increase over the pan station of about 61%. Figures reported by Smith (1990) for five factories varied between 38% and 71%.

The colours of various products predicted by the model compared favourably with measured values as shown in Table 1.

Table 1
Predicted and measured colours of various products

Product	Model	Measured
Syrup	20 000	19 716
Remelt	29 990	29 622
A-Masseccuite	22 840	22 960
A-Molasses	52 953	51 067
B-Masseccuite	60 821	60 170
B-Molasses	100 219	97 866
C-Masseccuite	97 663	105 205
C-Molasses	136 185	131 650
A-Sugar	1 323	1 096
B-Sugar	15 371	16 496
C-Sugar	36 739	31 415

The sugar colours predicted from the model are very dependent on the sugar purities assumed. The colours could be made to correspond to those measured by using 99,45 pol for A-sugar, 91,5 purity for B-sugar, and 84,4 for C-sugar.

It was therefore concluded that the model is fairly representative of a sugar factory and can be used for predictive purposes. The model as set up above was then used as a base case for further investigations.

Effects on change of process conditions on sugar colour

The model predicted an affinated crystal colour of 677 and simulating varying washing on the A-centrifugals gave:

Sugar pol	Colour
99,0	1791
99,1	1634
99,2	1478
99,3	1323
99,4	1168
99,5	1014
99,6	860

Reducing B sugar purity from 93 to 89 resulted in:

- 8,5% increase in A-sugar colour
- 1,7% increase in A-masseccuite
- 6,2% increase in B-masseccuite
- 0,4% increase in steam on cane.

Reducing C-sugar purity from 84 to 80 gave:

- 5,5% increase in A-sugar colour
- 0,8% increase in A-masseccuite
- 2,1% increase in B-masseccuite
- 0,3% increase in steam on cane.

Increasing A-exhaustion from 66 to 70, maintaining the same B-molasses and C-masseccuite purities gave the following results:

- Remelt colour increased by 10%. This was compensated by a decrease in quantity of remelt with the net result that there was a slight reduction in colour of syrup fed to the pans.
- Raw sugar colour was unchanged (three units reduction)
- 4,6% decrease in A-masseccuite
- 17,0% decrease in B-masseccuite
- 1% decrease in steam on cane.

Crystallisers and back boiling

The advantages of high exhaustions over the A- and B-stations are well understood, but in the South African sugar industry, the use of crystallisers with long residence times is an accepted practice to help achieve these high exhaustions. While the use of crystallisers on C-masseccuites is not questioned, A- and B-crystallisers could be eliminated if increased exhaustions could be achieved in the pans.

Although not practiced in the South African sugar industry, back boiling has been used as a means of increasing pan exhaustions, particularly in refinery pans.

Continuous pans should be well suited to back boiling, since molasses from the centrifugals can be fed back to the last one or two compartments in a controlled manner. This

could prove beneficial since higher pan exhaustions could be achieved at the same or lower crystal contents.

Although it may be expected that this will increase sugar colour, only the outer shell will be affected.

If A- and B-crystallisers are dispensed with, then colour formation in process will be reduced because of the lower residence time. Undetermined losses should also be reduced.

The model was therefore run to simulate a factory with no A- and B-crystallisers with back boiling on the A- and B-pans in the final stages of boiling. The following assumptions were made:

- The mother liquor purity in masseccuites leaving the pan using back boiling was similar to that in masseccuites from the crystallisers.
- Similar or slightly higher mother liquor brixes at strike were maintained on A- and B-boilings.
- Colour formation over the A-station was reduced from 8% to 5%
- Colour formation over the B-station was reduced from 15% to 8%

The following results were obtained:

- A-masseccuite quantity increased by 11,5% but this was dependent on the quantity of back boiling.
- Brix of A-masseccuite on strike was reduced from 92,8 to 92,4.
- Crystal content of A-masseccuite on strike was reduced by 2,8%.
- There was a 40 unit reduction in raw sugar colour. If pan colour formations were kept the same, the sugar colour would have increased by 38 units.
- B-masseccuite quantity was increased by 6,6% but this was dependent on the quantity back boiled.
- Brix and crystal content of B-masseccuite at strike were similar to those without back boiling.
- Steam on cane increased by 0,66%. This would be lower if V2 was used for boiling as is sometimes the case with continuous pans.

One of the limiting factors in achieving high exhaustions in the A-station is viscosity of masseccuite. At high crystal contents, circulation in the pan becomes a problem. With back boiling, however, indications are that similar exhaustions can be achieved at lower brixes and crystal contents. There is, therefore, the possibility that exhaustions could be improved further if crystal content were increased to levels similar to those achieved at present.

Conclusions

Indications are that the mass, energy, and colour balance model can give a good indication of colours of various process streams in the factory and can be used for predicting the effects of plant operating parameters on raw sugar colour.

An evaluation of the elimination of A- and B-crystallisers coupled with the introduction of back boiling has indicated that similar or better exhaustions can be achieved, and that raw sugar colour should not increase.

A disadvantage is that there will be an increase in quantity of masseccuites requiring an increase in pan capacity. In a new factory, this cost will be small in comparison to the saving in capital through not installing A- and B-crystallisers.

Additional benefits are the monetary savings associated with lower stock in process, and the reduction in boil-off time at the end of the season.

Although the increase in process steam demand could result in additional coal burned in some factories, it is believed that there will be a reduction in massecuite degradation and undetermined loss which will more than offset the cost of extra fuel.

Continuous pans should be ideally suited to the introduction of back boiling as the quantity can more easily be controlled and optimised. In addition, these pans normally operate on V2, so the increased steam demand will be lower.

Pan exhaustions may possibly be increased further by back boiling lower brix molasses to encourage higher crystal contents.

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