Optimization of Sugar-End Processing

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Introduction

During the 1970-71 season, the Holly Sugar Corporation Process Research Department studied sugar-end color. Emphasis was placed on color origin — noticeable areas of color development, color flow, and color recirculation. At the conclusion of this study, research was extended to the field of sugar boiling. Results from these studies and a recommended sugar end scheme, which is a practical application of the research findings, are presented in this paper.

Sugar-End Efficiency

The word efficiency as applied here is a measure of processing results as 1) a degree of equipment utilization, 2) amount of unnecessary solids recirculation, 3) steam and power consumption, and 4) degree of molasses exhaustion.

The elevation of the purity level in the sugar end enlarges the quantity of total massecuite solids[2] at a given non-sugar load as shown in Table 1. If the purity levels for white, high raw, and low raw massecuite are elevated from 92.0 - 84.0 - 76.0 to 93.0 - 85.0 - 77.0 or to 94.0 - 85.0 - 78.0, then the quantity of total massecuite solids is enlarged by 16.96% and 31.62% respectively. In a well designed sugar end, the percentage by which the massecuite is enlarged will equal the percentage decrease in sugar-end production and subsequently the beet slice. In addition to this, high sugar end purity levels adversely affect the potential molasses purity (5)[3] as expressed numerically in Table 2.

As indicated, a one unit purity increase in low raw massecuite purity increases the purity of molasses by about two units.

As shown in Table 1, the percentage of total massecuite solids increases as the non-sugar load increases. The non-sugars are introduced into the sugar end in thick juice, but the total amount of non-sugars in the massecuite is also a result of non-sugar recirculation. In order to compare the efficiency of several sugar ends, a magnitude which could be called "Unit of Total Massecuite" (U.T.M.) must be introduced. The U.T.M. is the percent total massecuite solids

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[1]Project Leaders, Research Department, Holly Sugar Corporation, Colorado Springs, Colorado.

[2]Sum of all massecuite solids expressed as % on beets.

[3]Numbers in parentheses refer to literature cited.

Table 1.—At a given non-sugar load, massecuite solids increase in the sugar end as the purity levels increase.

Sugar and Non-sugar entering sugar-end expressed as % on beets		Thick juice	Total solids in all massecuites expressed as % on beets for the following purity levels		
Non-sugar	Sugar	Purity	92-84-76	93-85-77	94-86-78
2.0	14.5	87.88	43.26	50.60	56.94
1.9	14.5	88.41	41.09	48.06	53.87
1.8	14.5	88.96	39.04	45.54	51.03
1.7	14.5	89.51	36.76	43.01	48.20
1.6	14.5	90.06	34.67	40.48	45.35
1.5	14.5	90.62	32.44	37.94	43.52
% Massecuite enlargement			0.00	16.96	31.62
Ratio of total solids in all massecuites to non-sugar entering the sugar end			21.63	25.30	28.47

Table 2.—The effect sugar end purity levels have on molasses purity.

Low raw massecuite purity	Molasses purity
81.0	65.0
80.0	63.2
79.0	61.4
78.0	59.5

on beets divided by percent non-sugar on beets introduced by thick juice. The numerical values are given for three purity levels in the last item of Table 1.

Increases in the U.T.M. means the loss of production occurs in several different ways. Two of these ways were investigated: 1) poor pan boiling technique resulting in frequent remelts or in the requirement for low colored standard liquor — meaning that more thick juice must be sent to the high raw side; and 2) low raw sugar recirculation to the high raw side.

White Pan Boiling

The initial studies attempted to define the relationship of massecuite color to produced sugar color as shown in Figures 1, 2, and 3. In Figure 1, no relationship exists, while in Figure 2 and particularly Figure 3 a fair relationship is noted. Microscopic observation of sugar from Figure 1 indicated the presence of numerous conglomerates. This observation initiated an evaluation of crystal quality.

A special sugar crystal quality procedure was developed by adapting existing procedures from the literature (2, 6) to the specific problem encountered. In this procedure, sugar crystals are classified according to their "crystal regularity" in the range 0-100 where 100 is sugar with perfect crystals and 0 is sugar containing all congomerates.

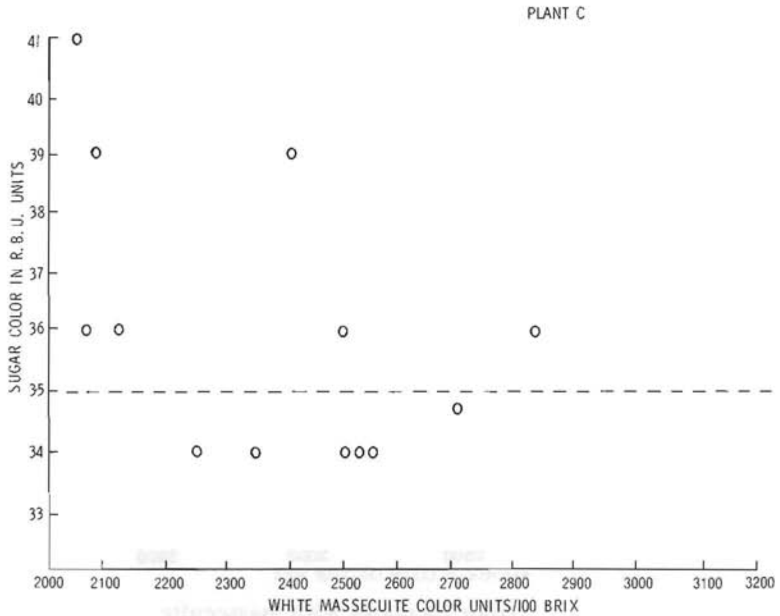


Figure 1.—No relationship of sugar color to white massecuite color is found in this figure.

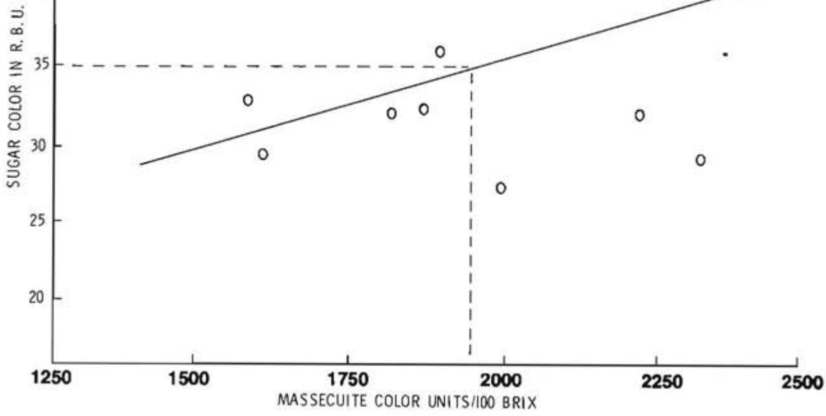


Figure 2.—Sugar color increases with massecuite color.

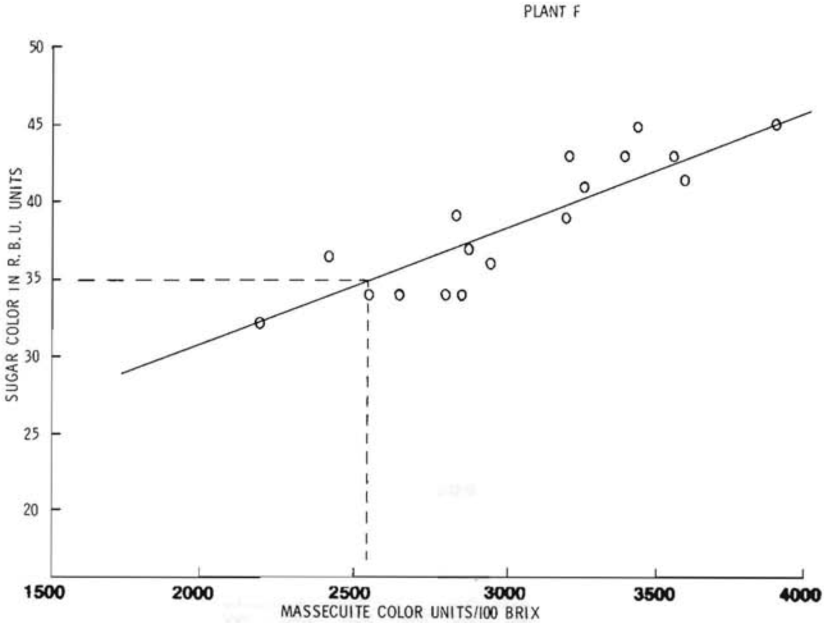
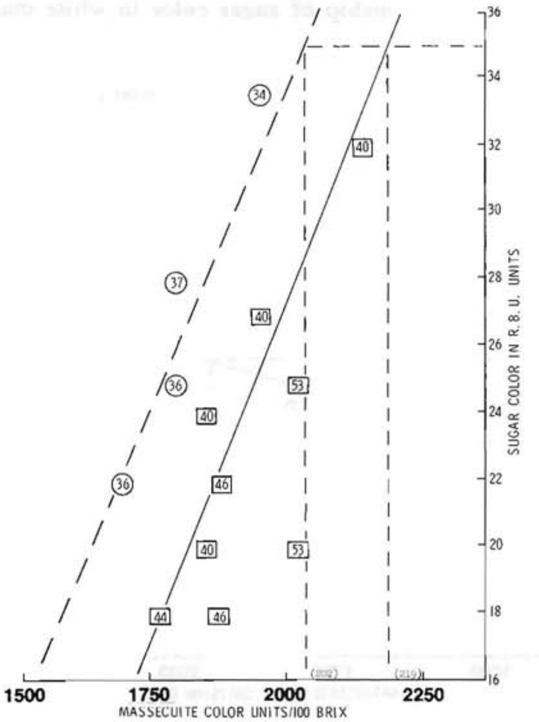


Figure 3.—Sugar color increases with massecuite color.



In Figures 4, 5, and 6, massecuite color is again related to sugar color with additional numbers representing sugar quality index. By connecting the points with the same or nearly the same sugar quality index values, a fairly good linear relationship is found. As read from the figures and compiled in Table 3, 35 R.B.U. sugar can be boiled from different colored standard liquor.

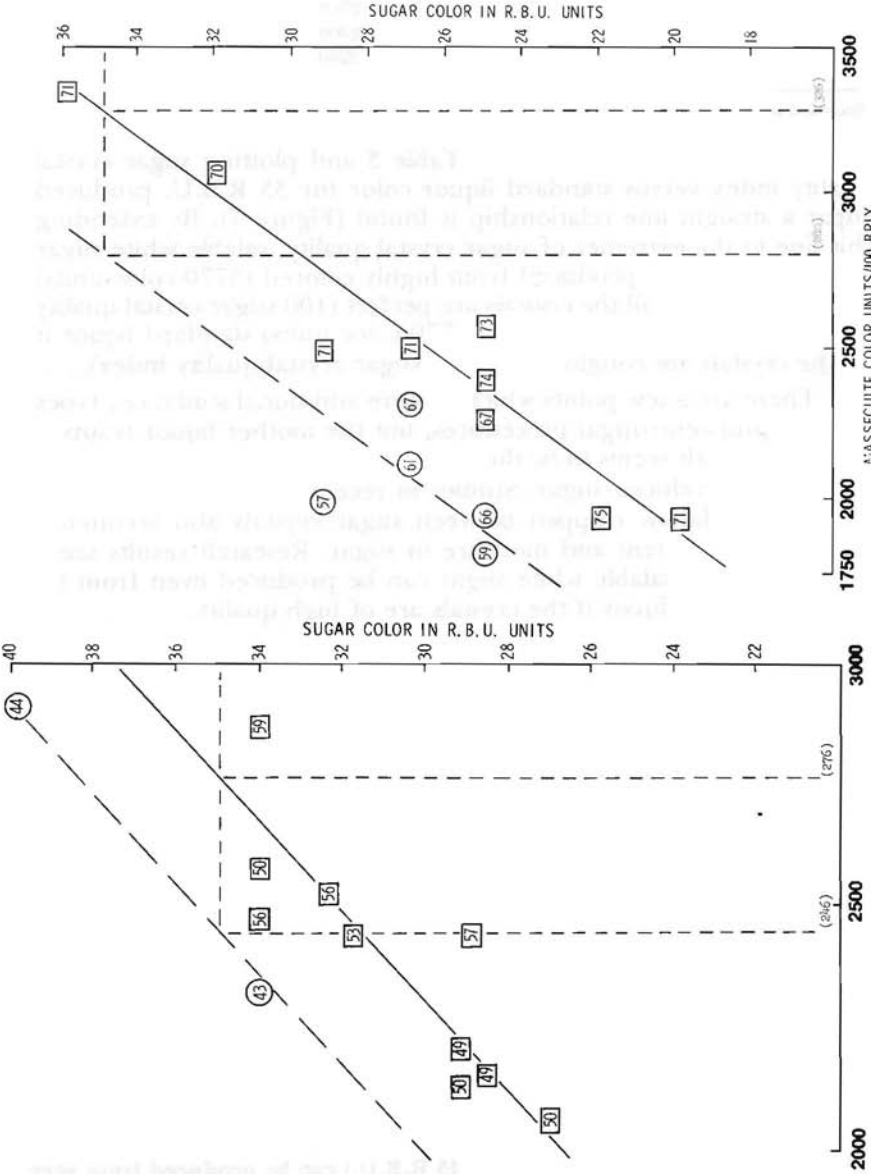


Figure 4, 5 and 6.—For sugar crystals with a similar quality index sugar color increases with massecuite color.

Table 3.—The relationship of sugar crystal quality to massecuite and standard liquor color for producing salable white sugar.

Plant	Sugar quality index	Color required in massecuite	Color required in standard liquor
C (Spring)	35	2020	1820
	42	2190	1870
C (Fall)	43	2450	2200
	51	2760	2480
F	60	2800	2520
	72	3260	2930

Standard liquor color is found to be an average of 10% less than massecuite color.

When taking the data from Table 3 and plotting sugar crystal quality index versus standard liquor color for 35 R.B.U. produced sugar a straight line relationship is found (Figure 7). By extending this line to the extremes of sugar crystal quality, salable white sugar (35 R.B.U.) can be produced from highly colored (3770 color units) standard liquor if all the crystals are perfect (100 sugar crystal quality index) and from nearly colorless (770 color units) standard liquor if all the crystals are conglomerated (0 sugar crystal quality index).

There are a few points which require additional study; *i.e.,* types of color and centrifugal procedures, but the mother liquor trapped between crystals seems to be the most significant factor causing color increase in produced sugar. Studies in recent years (4) have shown that mother liquor trapped between sugar crystals also accounted for high ash content and moisture in sugar. Research results seem to indicate that salable white sugar can be produced even from 90 purity standard liquor if the crystals are of high quality.

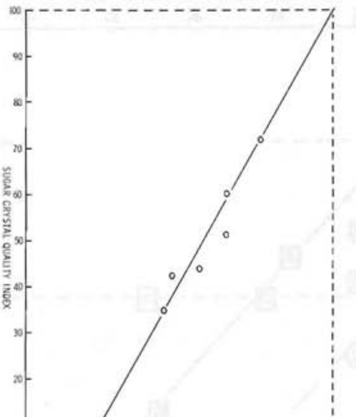
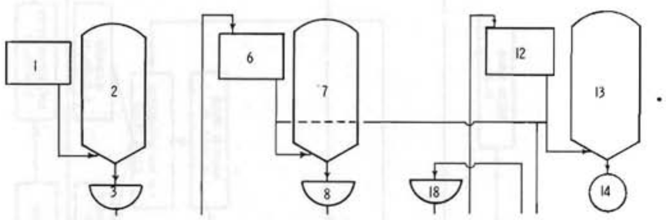


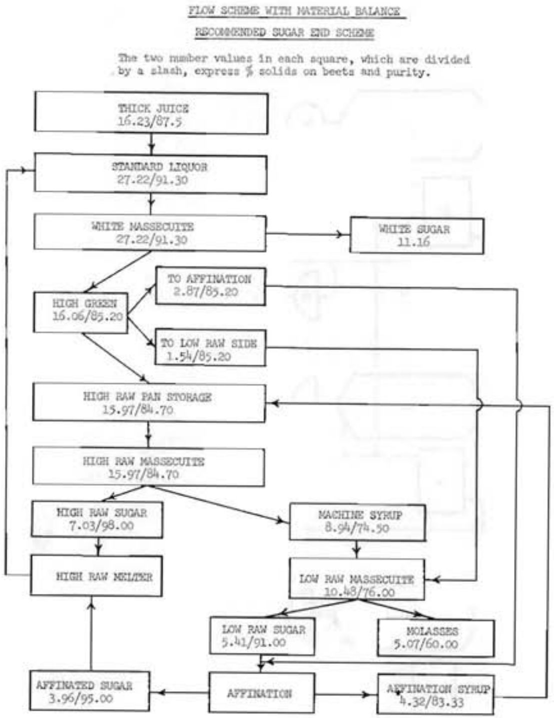
Figure 7.—Salable white sugar (35 R.B.U.) can be produced from very low colored standard liquor if the sugar crystal quality is poor quality is good (near 100).

While the scope of this report would not permit a complete discussion on pan boiling problems, a few ideas which are based on pan floor observation and supported by literature (1, 7, 8) are presented below:

1. Conglomeration takes place only in the first one-third of the pan boiling cycle where the crystal size ranges from 24 to 72 microns. In this part of the boiling cycle, evaporation is very fast while crystallization is slowed due to the small crystal surface.
2. There is an acceptable assumption that crystals are conglomerated due to the high gradient of osmotic pressure caused by high sugar concentration differences between two crystals. This assumption is supported by the fact that almost no conglomeration occurs in low grade boiling.
3. For the fastest rate of boiling with minimum production of false grain, fines, and conglomerates, there is an optimum tightness of the massecuite during the whole boiling time. In other words, there is one optimum crystal concentration or one optimum distance between the crystals, given numerically as 200 microns. If the distance between crystals exceeds 500 microns, excessive conglomeration is to be expected unless the boiling is extremely slow (very slow supersaturation) with subsequent loss of production.
4. Existing vacuum pans, when supplemented by full seeding, agitators, and available automation, can meet the requirements for boiling salable white sugar from high colored and lower purity standard liquor. Evaluation of every pan with respect to optimum boiling conditions could contribute to pan floor and sugar end productivity.

RECOMMENDED SUGAR END SCHEME





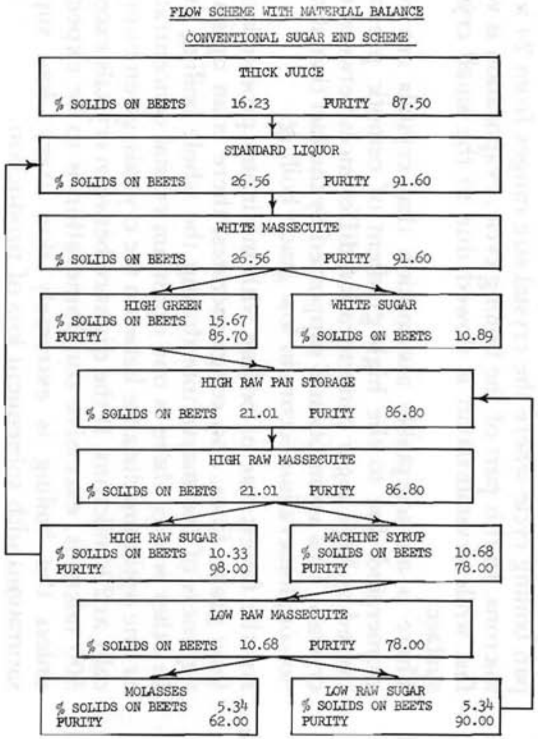


Figure 8, 9 and 10.—Self-explanatory.

Recirculation of Low Raw Sugar

When considering sugar end efficiency, the best place for low raw sugar return is the white side, provided the sugar color is less than 2000 units/100 Brix. the ciasic method for obtaining this low colored sugar is to wash with water during centrifuging, but this maximizes sugar losses in molasses. Molasses on the surface of the low raw sugar crystal can also be minimized if the massecuite is heated to the saturation point before centrifuging. Unpublished research results from the Holly Sugar Laboratory indicate that at least 9% of the molasses remains on the sugar crystals when spinning under ideal laboratory conditions (82.5 molasses Bix, 60°C temperature, ¾ inch sugar wall thickness, and 1400 R.P.M.—centrifugal velocity). Assuming molasses-free sugar contains 1200 color units/100 Brix, then 2000 color units/100 Brix sugar can be produced in this case if molasses is of less than 12000 color units/100 Brix. Molasses in California ranges from 40000-60000 color units/100 Brix! From the facts presented above, the purging of low raw sugar seems to be suited to the affination process.

The process called affination has been part of the beet and cane process for a number of years, with the most recent description of successful application in 1962 (3).

Recommended Sugar End Scheme

The recommended scheme is based on the discussion to this point and is shown in Figures 8 and 9. This scheme requires optimized white pan boiling and follows the same process pattern as the conventional sugar end scheme (Figure 10) to the point of graining the low raw pan. A low raw pan graining charge is prepared by adding a portion of the high green and machine syrup to obtain a mixture of 79.60 purity[4] in order to have normal graining. Machine syrup is added as a feed following the graining to achieve a final massecuite purity of 76.0. Water is added at the point of pan discharge to achieve the optimum non-sugar/water-ratio.

The calculated cooling end-point temperature should be achieved by cooling at a uniform rate. Massecuite should be warmed 3 - 4°C in the mingler prior to centrifuging.

Low raw sugar is mixed with high green in the affinator (point 16, Figure 8) and the obtained product "magma" is transported by a massecuite pump (point 17) to the magma mixer (point 18) which is above the continuous centrifugals (point 19).

Affinated low raw sugar goes to the high raw melter (point 10) and the centrifuged green goes to the high green receiver (point 5).

As shown in Table 4, the recommended scheme has the following advantages over the conventional scheme: a. 8.53% less total mas-

[4]Dry substance and purities in this paper are determined by the refractometer using 1:1 dilution.

Table 4.—Sugar end material and color balance — recommended and conventional scheme.

	Recommended			Conventional		
	% Solids on beets	Purity	Color (425mu) 100 brix	% Solids on beets	Purity	Color (425 mu) 100 brix
1. Thick juice	16.23	87.50	2000	16.23	87.50	2000
2. Standard liquor	27.22	91.30	1660	26.56	91.60	1670
3. White massecuite	27.22	91.30	1750	26.56	91.60	1760
4. White sugar	11.16	85.20		10.89		
5. High green: Total	16.06			15.67	85.70	
Affination	2.87	85.20				
Low raw side*	1.54	85.20				
6. High raw pan storage	15.97	84.70		21.01	86.80	
7. High raw massecuite	15.97	84.70		21.01	86.80	
8. High raw sugar	7.03	98.00	1000	10.33	98.00	1000
9. Machine Syrup: Total	8.94	74.50		10.68	78.00	
10. Graining	1.60	74.50				
11. Combined syrup for graining	3.14	79.60				
12. Low raw massecuite	10.48	76.00		10.68	78.00	
13. Low raw sugar	5.41	91.00		5.34	90.00	
14. Molasses	5.07	60.00		5.34	62.00	
Affination						
15. Low raw sugar	5.41	91.00				
16. High green	2.87	85.20				
17. Mixture	8.28	88.88				
18. Low raw affinated sugar	3.96	95.00	1500			
19. Affination syrup	4.32	83.33				
20. Affinated from low raw sugar	1.45	80.00				
21. Total massecuite on beets	53.67			58.28		

*For Graining

ASSUMED VALUES FOR CALCULATION

Sugar content in Cossettes	15.00% on beets
Total sugar losses	0.80%
Thick juice color	87.5
Standard liquor color	2000. units/100 Brix
Produced sugar color	Less than 1700. units/100 Brix Less than 35.0 R.B.U.

secuite; b. 31.56% less high raw massecuite; c. expected extraction increases 0.27% on beets or 1.80% on sugar; d. less steam and power requirements; and e. the investment is small because the idle high raw machines are available for affination work.

Conclusions

1. With automatic pan boiling equipment the potential exists for rapid boiling of good quality sugar from lower purity and higher colored standard liquor. This is an essential point for maintenance of optimum sugar-end purity levels.

2. Efficient sugar end operation is achieved by avoiding unnecessary recirculation of color, non-sugars, and sugar.

3. Low purity low raw massecuite has a decisive effect on molasses exhaustion. Since low purity sugar beets bring a high load of non-sugar to molasses, optimum molasses exhaustion is a vital point for achieving maximum extraction and satisfactory profit.

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