Experiments in Vacuum Pan Control

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The primary purpose of the present work was to increase pan floor capacity by improved vacuum pan operation and to develop a control system that would enable any person to boil consistently good strikes.

A material balance showed that it was first necessary to improve white pan yields. An increase from the normal 40% to 60% could reduce total fillmass almost 50%. It would cut white fillmass by one third and high raw by an astonishing two thirds.

We were fortunate to have available pan microscopes, first a foreign model and later very excellent domestic units. The picture they gave of crystal growth within the pans themselves exploded some conventional theories and helped prove others. By watching the course of strikes boiled by even skilled sugar boilers it was apparent that there was a great deal of room for improvement.

In order to increase yield of finished sugar per strike it was necessary to boil grain of more uniform size and with a minimum of conglomerates. Such clean strikes around 60% yield were found to purge better and require less wash than poor strikes with yields below 40%. Better control of mean aperture was required which indicated the need for full seeding rather than by shock.

Rate of crystal growth depends upon supersaturation and syrup purity. In a typical standard liquor at maximum safe supersaturation, crystals can grow at a rate of about 0.016″ per hour measured on the mean dimension. This is equivalent to about 3.5 microns per minute on each face. The pan microscopes disproved the existence of a supersaturation zone in which crystals form spontaneously only in the presence of other grain; above a very definite supersaturation, about 1.50, grain would form in syrup or at any stage of the strike. This simplifies the picture in that only one zone between 1.00 and 1.50 supersaturation is of interest in sugar boiling. If clean strikes were to be produced from an original seed crop, it was imperative that the upper limit never be exceeded; maximum rate of growth, however, would be realized just under this limiting supersaturation. In the interval just after graining when crystal area was low, it was easy to exceed the safe value and form more grain. In spite of

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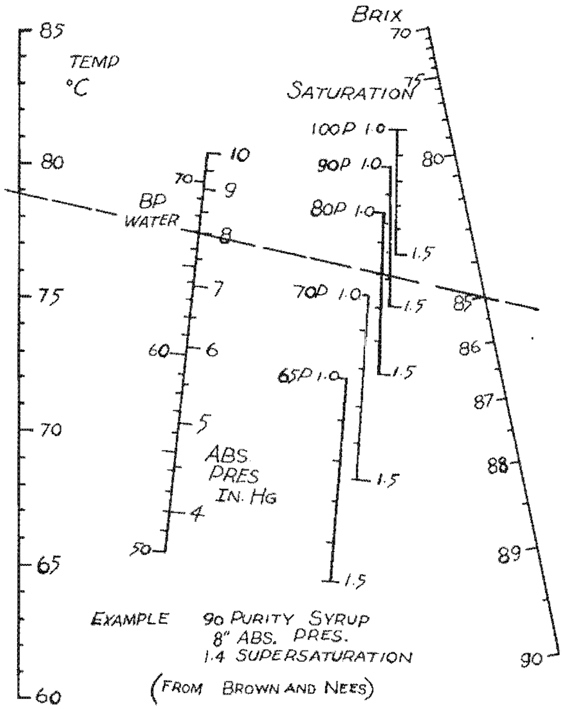
the vastly increased crystal area during final brixing the limit could again be reached since cutting off feed liberated sugar some eight times as fast. Fine grain formed at this time goes through the centrifugal screen instead of being deposited on the existing crystals and is lost from the pan yield. On coil pans, premature addition of one coil to many in the middle of the strike could also create a smear.

Interestingly, the pan microscope disproved the notion that fine grain formed during the course of a strike can be washed out by a large drink of feed. Grain will only dissolve in liquor below saturation and it would require a volume of 70 brix feed almost equal to the fillmass volume at any time to reduce a pulled together strike to saturation. What actually happens is that the fine grain conglomerates and grows rapidly so that in a few minutes the strike looks clean again in the sight glasses or on a slide but in the microscope the new ones are all there growing along with the larger original crystals.

Conventional methods of measuring supersaturation were found inadequate for the precision boiling we sought. Boiling point measured in the side or center-well of a pan is affected by material that bypasses and reaches the bulb without dropping to the temperature and pressure at the fillmass surface. A means was developed to measure temperature at the surface which is the most highly supersaturated region; this coupled with a precisely controlled absolute pressure gave a reliable reading of supersaturation throughout the strike.

The actual absolute pressure at which a strike is boiled seems to be of secondary importance since equally good strikes can be produced over quite a range of pressures. The value selected is determined more by considerations of water supply and steam pressure. At any given absolute pressure, the temperature corresponding to the supersaturation limit can be determined approximately from the alignment chart of Figure 1 which is based on the data of Brown and Nees (1). The actual value for the limit on a particular syrup is precisely determined by means of the pan microscope which is a necessary part of a precision boiling system. The most direct way to fix the value is to gradually raise the pan temperature until the appearance of new grain shows that the limit has been exceeded; they are visible within seconds after they form. Or the saturation point can be determined by introducing a bit of powdered sugar into the graining charge as it is being concentrated and noting the temperature at which the crystals first show corners.



EXAMPLE 90 PURITY SYRUP
8" ABS. PRES.
1.4 SUPERSATURATION

(FROM BROWN AND NEES)

Figure 1.—Supersaturation chart for beet sugar syrups of various purities. At a controlled absolute pressure in a pan, the boiling temperature at the fillmass surface indicates the degree of supersaturation; it must be held below 1.5 to prevent formation of new grain.

Boiling time is generally fixed by the heat transfer rate in a given pan but it was found that the pan cycles could be shortened by bringing the pan together as soon as possible, and carrying an optimum tightness during the feeding period. This seeming paradox that a tight strike is "looser" than a loose strike is probably due to the fact that for the same supersaturation gradient, the average syrup concenration is reduced as the crystal faces are brought closer together with corresponding decrease in viscosity. If tightened excessively, the overall fluidity is reduced by the increasing crystal concentration and heat transfer is reduced. A probe has been developed to record tightness and control feed to maintain it at the optimum which is of the order of 20% yield. A 10 to 20% reduction in boiling time can be realized by so doing.

The problem of conglomeration was not an easy one but some of the factors contributing to the formation of multiple grain were established. Their complete elimination was not realized but it was possible to reduce the number to a small fraction of the total grain.

Observation showed that most conglomeration takes place when the crystals are quite small, 0.001 in to 0.003 in size. Before and after this dangerous age there is almost none. Carrying the strike at lower supersaturation or looser during this interval has little effect. Some improvement was noted by boiling at higher absolute pressures. Purity has a great deal of influence; conglomeration is almost no problem at all in the lower purity syrups. One plantation in Hawaii noted for its excellent boiling house work grains in low purity syrup and then switches to feed of higher purity.

Apparently vigorous circulation during the conglomeration period is the only cure. Mechanical circulation is very helpful but needs to be supplemented by some boiling. Open steam is useful in pans without mechanical circulation but is much less effective than the same amount of steam flow to the heating surface probably because of the local circulation created by the formation and liberation of vapor bubbles. Surface within the pan over which the boiling material can shower and spread further deters conglomeration; a coil pan is better in this regard than a calandria pan at twice the boiling rate.

In pans without mechanical circulation, conglomeration can be held down by rapid boiling but the conglomeration period occurs when the crystal area is too small to absorb the sugar liberated by the boiling. This dilemma is solved by reducing the steam flow only to a value that discourages conglomeration and feeding water to prevent the supersaturation from exceeding the upper limit. Within a few minutes, as the crystal area increases, the water flow is reduced to zero and boiling rate can be increased.

As these techniques were developed it became possible to boil consistently good strikes with low CV values, obtain high yields of well-formed grain and do them in minimum time. The final problem of introducing the correct seed crop to produce the desired final crystal size was solved by borrowing a technique that has been used in Hawaiian mills. Laboratory ball mills are charged with sugar and iso-propyl alcohol in the proportion of 1 lb to 1 liter. After grinding for 24 hours, the particle size has stabilized at an average of about 4.5 microns and the resulting density is around 2.5×10^9 particles per milliliter. Approximately 200 ml of this "milk" is sufficient to seed 1,000 cubic feet of white fillmass for 0.015 in M.A. The actual amount for a particular pan can be adjusted until the required size is obtained and will repeat very well thereafter. Graining procedure is standardized by maintaining the same graining volume for each strike and introducing seed at the same supersaturation each time.

The immediate object of this work was not to produce a "push-button" pan control system but rather one which would make possible precision boiling of the most high-quality sugar from a given pan in the least possible time. The operations of dropping and steaming out as well as introducing seed have been left to the sugar boiler since the additional complexity and cost seem hardly justified. Nevertheless, the system, though only semiautomatic does reduce the time and attention normally required to a great extent. As the controls are arranged, variations in feed concentration or steam pressure are taken care of automatically. No adjustment of the supersaturation limit is required except in the event of a drastic change in syrup purity. The same system is applicable to white, high raw or low raw pans since the problems are the same. A pan with mechanical circulator does not require a water make-up valve to hold supersaturation.

On the pan control panel there are four controllers, absolute pressure, level, supersaturation and tightness. Steam flow is indicated so that the optimum tightness value may be easily determined and checked. The strike is initiated by turning a switch which opens feed and condenser water valves. When level reaches the graining volume, steam comes on to concentrate the charge and the level is maintained. An alarm sounds when supersaturation rises to 1.3; the sugar boiler acknowledges the alarm and seeds the pan with a measured quantity of the wet milled fondant. As supersaturation rises to the 1.5 limit, steam is throttled so the limit will not be exceeded. As the pan comes together, the increasing tightness opens the feed valve to hold it constant. Whenever the combination of feed and increased crystal area cause the supersaturation to fall away from the limit, the steam valve opens to maximum.

Boiling proceeds until the pan reaches maximum set level, the feed valve throttles to prevent further rise and the pan begins to brix up. If at this time, the supersaturation increases to the set limit, evaporation will be reduced to prevent grain formation. This is a most important period since sugar is being deposited at the rate of many bags per minute; if hurried, it can only result in sugar being lost with the syrup and recirculate through the house.

As the tightness reaches the dropping point, the steam valve closes and an alarm notifies the sugar boiler that the strike is finished. He turns the switch to "off" and drops the strike.

The techniques and controls developed by this work achieved the original objective of increasing pan floor production. Reduced reboiling of syrups added economy dividends. To the less cost-conscious person, the sparkling sugar that emerged from the granulator and from the high and low raw machines was a delight to the eye.

Literature Cited

(1) BROWN, R. J. and A. R. NESS. 1933. Solubility of sucrose in beet house syrups. Ind. & Eng. Chem. 25 (5): 555-558.