Sugar Boiling
Some Useful Strategies

by ***John Ziegler***

A question often arises during discussion of sugar boiling as to whether there is one best strategy that will produce the highest yield of well formed, uniformly sized crystals in the least time and most economically. The answer is generally that a considerable number of variables have a bearing such as pan design, syrup purity and concentration, steam pressure, condenser capacity etc. Even so, it is possible to set down some good-practice rules pointing the way toward establishing the best possible sequence of operation for any one pan and the material it normally processes. Let us explore some of these major variables that must be considered.

Vacuum pans are as varied as fingerprints and even the best ones can stand improvement is design details. It is something of a wonder that we are able to produce reasonable results in these pieces of equipment and the capability of even the best ones can stand improvement by rather simple attention to certain details. The better pans are those having straight side walls, mechanical circulators, condensers with adequate capacity to maintain desirable and steady vacuum conditions, steam supply high enough to produce reasonable circulation and measuring devices to continuously monitor the important variables. The method of feed introduction is very important but is often a neglected detail. The reasons for these observations can stand some elaboration.

Experience with a great many pans indicates that the so-called "low head" pans with shells of larger diameter than the calandria tube sheets will not produce grain as uniformly sized as that from straight sided pans. This is due to the circulation pattern with the pans themselves; crystals trapped in a persisting area of low oversaturation do not grow as rapidly as those spending more time in a favorable environment.

Mechanical circulators are of assistance but their influence is somewhat indirect since they only improve circulation in the calandria area and do little for massecuite at higher levels. This is easily proved by holding a partially completed strike with circulator running but no steam on the calandria. In a relatively short time the grain will settle to a level a few inches above the upper tube sheet, showing that circulation above this is negligible. It is only the lift produced by vigorous boiling that produces circulation in the upper portion of the pan. The contribution of the circulator is that it increases heat transfer and produces greater vapor ebulition for a given steam pressure and so improves overall massecuite circulation.

On high purity pans especially, it is impossible to produce clean grain with minimum conglomerates without adequate circulation and, since this is primarily dependent on the rate of boiling, steam pressure must be high enough to insure good circulation. It appears that a temperature drop over the heating surface of at least 35^0C is needed on pans with mechanical circulation and 45 to 50^0C without. Otherwise a large percentage of the final crystals will be balled and agglomerated.

With inadequate steam pressure to maintain circulation, an alternative would seem to be to carry a higher vacuum to increase the temperature difference but this becomes a fool's game for two reasons. Crystal growth rate decreases with falling temperature for the same degree of oversaturation. This can be especially important on low purity syrups where every effort must be made to insure the highest possible rate of sugar accretion. The optimum boiling temperature for any massecuite lies somewhere in the 70-80^0C range. Growth rate probably increases at even higher temperatures but in order to prevent undue color formation it is usually held below 85^0C.

Boiling at low temperatures (low absolute pressure) acts to reduce pan circulation in spite of the greater temperature difference and the increased volume of vapor produced. The mechanism of heat transfer in a pan calandria is one of conduction since, even with mechanical circulation, the upward flow through the tubes is in the streamline region. Massecuite leaves the tube as a plug, heated on the outside. As these hot rivulets rise in the pan, they flash off vapor when the hydrostatic head of massecuite is reduced to their equilibrium boiling point and bubbles rise to the surface. At low absolute pressures, hydrostatic head has a greater depressing effect on bubble formation due to the changing slope of the vapor pressure curve. Under these conditions, the bubbles simply fizzle near the massecuite surface and do not give enough percolating effect to move the material below this level.

The choice of boiling pressure is sometimes dictated by the condensing equipment and cooling water temperature available. Water usage increases rapidly with falling pan temperature and it is imperative that steady vacuum conditions be maintained especially during the critical phases of precision boiling just before and after seeding time. One should select a boiling pressure that can be maintained by the condenser. In warm climates, it is usually necessary to run at higher temperature especially if pan condensers are of borderline capacity.

Syrup Oversaturation

Other conditions being equal, crystal growth rate appears to be in direct proportion to the degree of oversaturation of the surrounding syrup which makes it the most important variable in sugar boiling. There is a distinct upper limit which cannot be exceeded without formation of false grain; this point lies right around 65% oversaturation (defined as the solids dissolved in the syrup above the quantity which would just saturate the same amount of water at the given temperature and purity.) For example, a saturated solution of pure sucrose at 75^0C contains 3.4615 gm. sucrose/ gm. water (77.6% solids). If concentrated to (1.65 x 3.4615) = 5.7115 gm. solids/ gm. water (85.1% solids) it is 65% oversaturated or its supersaturation is 1.65.

Syrup concentration in an operating vacuum pan can be measured in several ways but the most practical method to date appears to be by the boiling point of the syrup at a known absolute pressure or by its boiling point relative to that of water at the same pressure. This so-called boiling point elevation increases with absolute pressure or the corresponding water boiling point so a direct measurement of oversaturation is needed under drifting vacuum conditions, as provided in devices such as the Ziegler Oversaturation Monitor. The point in a pan at which the syrup boiling point is measured is very important.

There has been much wishful thinking about the circulation pattern in operating pans. Designers like to picture a column or rivulets of hot material rising in the area above the calandria tubes, flashing off vapor as the hydrostatic head drops off near the surface and then descending sedately in a column down through the center well to be reheated as it spreads outward and upward through the calandria tubes. The true picture is much different. Some of the hot material rising from the tubes near the center well is caught in the downward flow and never reaches the surface so it recirculates without cooling to the temperature corresponding to the vacuum at the surface. A Measure of temperature in the center well becomes valueless as pan level increases due to this by-passing which may keep material in the center well several degrees hotter than the equilibrium at the surface. In high purity syrups, the boiling point changes about 4.5^0C between 0 and 65% oversaturation. Neither is a temperature measurement in the side of a pan of use for accurate measurement of syrup concentration.

The greatest oversaturation occurs at the upper massecuite surface because it is at the lowest temperature of any point in the pan. The mechanical difficulties of measuring the boiling point at a continually changing level are best overcome by using the temperature of the super-heated vapor leaving the pan which will be essentially the same as that of the surface massecuite. This method has been used for years and has proved to be a most reliable means of monitoring oversaturation.

Syrup Feed

Many have very poor arrangements for introducing syrup or water feed Syrup introduced anywhere in the center well area is not swept outward under the lower tube sheet because velocities in that part of the pan are negligible. Due to the considerable difference in density, the feed simply floats to the massecuite surface and does not mix with the rest of the pan contents. Feed entering under a mechanical circulator has a better chance of being mixed unless the feed is hot enough to flash at that point. If flash does occur, it simply turns to foam and stops the action of the circulator which spins helplessly in the mass of soapsuds without biting on massecuite. Feed should be introduced well out under the calandria surface and not just at one point but many so that all possible mixing is achieved as it rises through the tubes. Flash of feed at this location aids pan circulation.

Crystal Growth Rate

Basic Vacuum Pan Instruments The average rate of growth in a vacuum pan falls short of maximum because temperatures in lower parts of the pan are higher than at the surface and oversaturation correspondingly lower.

Consistency

The viscosity of a sugar syrup depends on its temperature and concentration but, surprisingly, at equal oversaturation level it remains almost the same at different boiling pressures; the effect of temperature is balanced by the higher concentration. The overall viscosity or "consistency" of a given syrup is increased by the presence of sugar crystals in suspension. According to Silina, the effect is not great below 20% crystals, around a 2.5 times increase over syrup viscosity. But at higher yields the factor increases rapidly, reaching 22 times at 45% crystals.

In the interest of good pan circulation, crystal yield should be held below 20% during as much of the pan cycle as possible and allowed to increase to dropping consistency only at the end of the strike. There are situations where boiling time can be reduced by an earlier rise of consistency at the expense of loss of circulation and attendant crystal formation. These situations will be explained together with others calling for less than ideal operation.

Equipment and Facilities

In order to better explore the options available in pan manipulation, it might be well to assume a reasonably good pan is available and the auxiliary equipment is in good order.

Our pan has a striking volume of 1600 Cubic feet and 2400 square feet of heating surface (45 M^3 and 223 M^2). Steam is available at 15 psig. 1 kg/cm^2. Condenser and water supply are capable of maintaining any steady pressure between 4" and 10" Hg. Abs. and is equipped with an automatic vacuum controller. A Consistency Monitor and controller is connected to a pan feed valve and the Monitor adjusted to read 0 with the rotor running free and 100% when stalled-infinite viscosity. An indicating Oversaturation Monitor has been adjusted to read 65% at the upper limit of the metastable zone over the range of purities to be boiled in the pan. This basic control system is diagrammed in Figure 1.

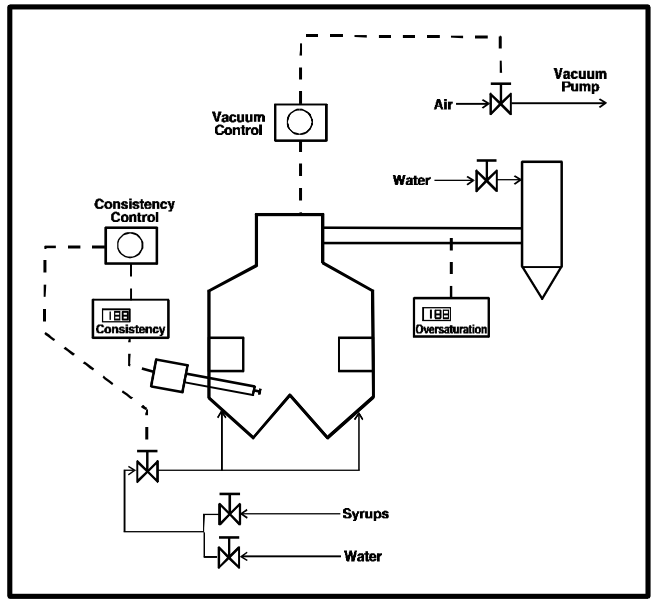

Figure 1
Basic Vacuum Pan Instruments.

Boiling High Purity Syrups

The optimum strategy for boiling high purity syrups is the more exacting and will be taken up first. Syrup at 93-95 purity (typical beet white strike) or higher purity cane refinery syrups including "plantation white", is to be boiled to clean sugar in the 0.015” to 0.030" size range. The syrup is at 65% solids and is being held at 80-90^{0}C in the pan storage tank.

When the pan is closed and vacuum applied, a suitable Training charge of syrup is introduced to a level near the upper tube sheet and steam is turned on. The absolute pressure is controlled at 7" Hg. Abs.

As the syrup concentrates, oversaturation comes on scale and slowly rises; the Consistency indication also increases with syrup viscosity. The first decision required is when to introduce seed; hopefully the best type, wet milled fondant is available and previous experience dictates that the desired grain size of 0.016" is reached with 300 ml of fondant slurry so this amount is measured out.

Theoretically, seed particles should be sustained and grow at any syrup concentration within the metastable zone between 0 and 65% oversaturation Practically, if introduced at too low a level of syrup concentration, many of the tinier nuclei will be melted out in the undersaturated regions near hot surfaces; if seeded and held near the upper limit, excessive conglomeration will occur. Yamane & Kamoda determined that conglomerate formation is directly proportional to oversaturation and many observations confirm that it occurs mainly when crystals are passing the 0.001 to 0.002" size range. Experience indicates that a good compromise is to seed in the 40-50% oversaturation range and hold at this level for 10-15 minutes until crystals have passed the critical size range.

Accordingly the pan is seeded with the measured fondant at or near 45% oversaturation being careful not to introduce enough air to cause a vacuum disturbance that would upset the oversaturation measurement. Contrary to opinion, air bubbled through syrup below the oversaturation limit does not cause additional nucleation. After seeding, a proof sample should be withdrawn and given a quick check with a 30-50 power microscope to be sure that the grain is present and growing with sharp crystal edges, and that the crystal crop in the microscope field appears to be normal. The Consistency control is then set at the existing reading, say 30%, to start syrup feed and maintain the same reading of oversaturation.

In approximately 15 minutes, a microscope check shows most of the grain to be in the 0.002 to 0.004" size range and growing nicely. The consistency control set point can then be increased to cut feed and allow the oversaturation to rise to 60% or so and control again at the higher level. Crystal growth rate is increased because in this stage of a strike one wants to increase crystal area as fast as possible without forming any new grain.

In a short time, it will be noticed that the oversaturation reading is slowly falling. This is because the crystals are taking up a larger portion of the sugar made available by water removal. Concentrating the syrup feed from 65 to 83 brix (60% oversaturation at 75^0C) requires the removal of 35/65 - 17/83 = 0.538 - 0.205 = 0.333 gm. water per gm. solids, but the sugar deposited on the crystals and thus removed from the syrup require evaporation of 0.538 gm. water/gm crystals.

Thus as crystal area increases, the amount of water introduced with feed must be reduced to maintain syrup oversaturation. Accordingly the consistency control set point should be increased in small increments to hold oversaturation in the 60-65% range. This phase of pan operation is called "pulling together", which means increasing the crystal/liquor ratio to a suitable boiling consistency.

After three or four upward adjustments of consistency, it will have gone from say 30 to 40% of scale. Examination of a proof slide shows the grain tumbling over one another with no gaps forming as the massecuite runs down the slide. The crystal yield will be in the 15-20% range and the strike has been safely pulled together. Pan level will be around 40% of the way from seeding to striking points.

Then starts a relaxed phase of the pan cycle. The consistency is at a proper value for good massecuite circulation and the constantly increasing crystal surface area will result in a slow decrease in oversaturation. The pan is perfectly safe and the sugar boiler can have a smoke or attend to other duties.

When the pan reaches maximum level, the consistency control set point is raised or syrup feed shut off. By this time, oversaturation is down in the 40-50% range. Shortly, with no water coming in with feed, the oversaturation begins to rise and becomes the important variable again. Consistency begins to rise toward dropping tightness. As oversaturation increases, sugar deposition accelerates and the rising consistency reduces the evaporating rate. The results of these two effects is that the oversaturation rises more slowly and in the final minutes of the strike usually begins to fall.

Final Brixing

One of the objects of good pan work is to obtain the highest crystal yield that can be dropped from the pan in reasonable time and handled in equipment beyond that point. A massecuite that requires five to ten minutes for discharge is generally about right. The cleaner and more uniform the crystal crop, the greater the yield for a given consistency at drop.

During the final concentrating phase, excessive oversaturation levels only result in the formation of fine grain which adds nothing to the yield and causes problems in centrifugals and dust in the drying and storing operations. A good part of pan yield is obtained during brixing up when sugar is being deposited at rates in excess of a ton per minute. So rather than hurry the process by allowing excessive oversaturation, it is better to take a few more minutes and lay the sugar on existing crystals than to form wasteful fines.

There are two obvious ways to maintain oversaturation below the upper limit during the final tightening process. Steam may be throttled to reduce the evaporating rate but this hurts massecuite circulation just when it is poor at best. A better, if less economical alternative, is to maintain maximum evaporation and feed a little water to hold syrup concentration in the safe region until increasing crystal area and decreasing evaporation will absorb the liberated sucrose.

Pans equipped with mechanical circulators usually show a smooth increase in consistency to the last; with natural circulation, the measurement is sometimes erratic due to stratification of material around the consistency probe and it becomes necessary to rely on proof stick samples. Some pans may require higher steam pressure toward the last to lift the grain. Without this crutch, the massecuite can be heavy near the bottom but still sloppy near the surface.

Purity Compensation

When boiling other than quite high purity syrups, the mother liquor purity decreases with pan crystal yield. For example, a 93 purity beet sugar white pan when pulled together to a 15 or 20% crystal yield on total solids will still have all the nonsucroses in the liquor but it has lost some sucrose as crystals and the purity will be down around 91.5. There is no need to compensate for this by readjustment of Monitor purity dials because it only amounts to a 1 or 2 percent change in actual oversaturation and little is gained by running the pan right up against the limit; better to stay in the 60-63% range at maximum.

Not much point in crowding ones luck trying to gain a slightly higher crystal growth rate. But the pan of this example, during the final brining up, will have a crystal yield around 40 some percent and the actual liquor purity will be down around 88%. (Note that 40% yield is far too low from a beet white pan but remember that the liquor is still highly oversaturated at drop and grain continues to grow in the mixer, rapidly dropping the syrup concentration toward a normal 55% yield or higher.)

In the last few minutes before dropping with the liquor around 88 purity the Monitor can be reset to the estimated purity and indicate that the actual oversaturation is somewhat lower. But it has been found easier to leave the purity dials set for the major part of the strike and determine how much the indication can be allowed to increase right at the end. This is easily done by making frequent microscope cheeks on a strike or two and noting the reading when fine grain "sparklers" begin to appear between the more mature crystals. It is found on this particular syrup that the oversaturation indication can be allowed to rise to 73% just before dropping the pan. Knowing this can cut a few minutes from each pan cycle without reducing pan yield or massecuite quality.

A chart of typical pan conditions during the high purity strike described is given in Figure 2.

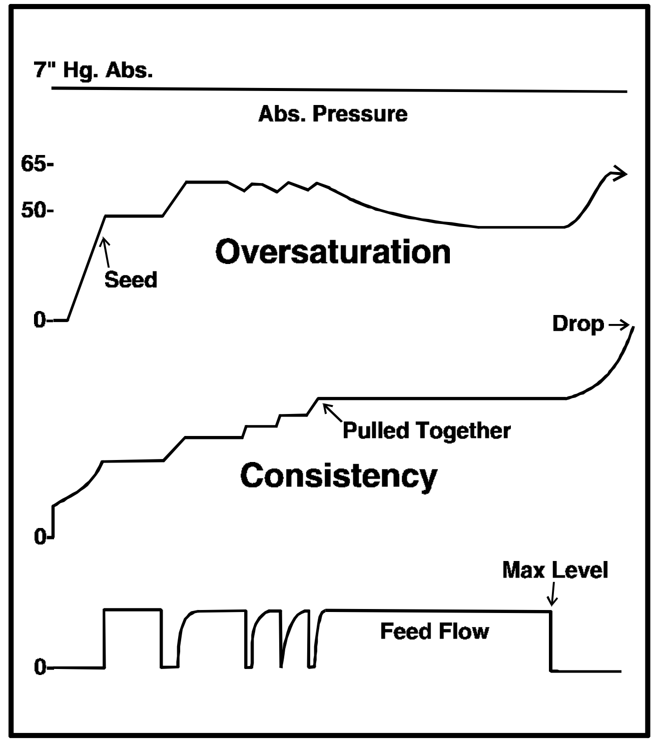

Figure 2
Typical High Purity Pan Cycle.

Light Feed Syrup

The time required to boil a strike of sugar from seeding to drop is determined either by the time to evaporate the necessary water from the feed syrup or the time needed to grow crystals of the desired size. As already noted, there is an upper limit on the rate of sugar deposition so clean crystals cannot be grown faster than about 0.010" per hour even from the purer syrups. A typical pan boiling normal granulated sugar of about 0.016" grain size, if fed with syrup in the 65 to 70 brix range comes out about even regarding the two time limitations. During final brixing, the oversaturation almost, but not quite, reaches the top safe limit.

Lighter syrups make for easier pan operation although steam consumption is increased. Boiling follows the same sequence as in Fig. 2 but more time is required. During the initial stages after seeding, feed rate is lower because of the greater water content so pan level rises more slowly although crystals grow at the same rate so the massecuite pulls together at a lower level. Once on consistency control the slower level increase requires more time to fill the pan so the over saturation will be lower when that point is reached; brixing will be complete before the oversaturation limit is reached.

Heavy Feed Syrup

If one is faced with a "hot" pan that boils rapidly, heavy feed syrup or the need for large crystals, evaporation time will be less than that for completing grain growth. The pan can still be boiled as before, but the increased feed flow required to follow the pattern, can result in a pan full of syrup near the safe oversaturation and not even pulled together to a proper crystal/liquor ratio. The pan has the right number of crystals but they have not had time to grow to final size, the pan is full so feed must be shut off and it must somehow be brixed up to dropping consistency. Prayer or burnt offering will not help; the pan must be held on water feed or reduced steam flow or both to keep oversaturation just below the maximum until brixing is complete.

Rather than waiting until the pan is full, it would be an advantage to hold it at a lower level for better circulation as soon as it is evident that the pan was filling too fast. At mid level, some water feed could have been introduced and the syrup feed reduced to slow the level rise, or it could as well have been held only on water feed for a time until the massecuite pulled together and then returned to syrup feed. Less holding would then be needed at the higher levels where mixing and circulation are inferior.

This should make it clear that for a given pan and crystal size specification, nothing is gained in steam economy or time by supplying syrup at too high a concentration. Some factories have simplified pan floor operations and the need for operator supervision by standardizing syrup brix ahead of the pans to stay within the capabilities of the pans and stabilize the day to day operation and produce consistently good sugar.

There are compromise strategies that can be used to speed grain formation in "hard boiling" syrups without loss of steam economy and only minor concessions to good boiling practice. One will be noted here.

When pan floor situations are such that most strikes must be held back during final brixing to extend the time for grain growth, a few minutes can be saved by starting to increase massecuite consistency before the pan is completely full. This will increase oversaturation and increase the crystal area before feed must be shut off. True grain quality and circulation may suffer somewhat during that period but less consistency increase is required during final brixing and more crystal area is available for sugar deposition so the need for water addition can be lessened and a few minutes per strike saved. But this should be regarded as a stop-gap measure. Some sugar boilers firmly believe that massecuite should be progressively tightened as the strike progresses but this means running at lower than necessary consistency in the early phases when circulation is better than it will be at high levels and this practice should be discouraged.

Another strategy for increasing crystal growth during the safe part of a strike is available after the massecuite is pulled together but is normally not needed in high purity boiling so a description of this technique will be covered under "low purity boiling".

Unusual Situations
Inadequate Feed Syrup

On even the best regulated pan floors, there will be times when the optimum boiling patterns will require modification but operators versed in the importance and limits of the prime variables of oversaturation and consistency can maintain good conditions in spite of upsets and bring partially completed strikes to a successful conclusion. If, during the course of a strike, feed supply fails or it appears that there will not be enough to complete the pan, there is no cause for alarm. Simply add a slow fixed feed of water and the consistency control will quickly reduce syrup flow to maintain proper conditions. If no feed is available, switch to water feed and let consistency regulate it. At a fixed consistency, the oversaturation will slowly fall toward a safer level, grain will grow more slowly and pan level will remain constant but the crystals already present will not be harmed; in fact they will get cleaner and cleaner as growth rate slows. When syrup supply is restored, cut off water and replace with syrup to complete the strike. During the respite, oversaturation will have dropped to a safer value and more "outage" will be available during final brixing to stay below an unsafe limit during that operation.

Loss of Vacuum

When a partially completed strike suffers a loss of vacuum for one reason or another, immediate action must be taken because the rising massecuite temperature will soon begin to melt out the crystals present when syrup falls below saturation. The first thing to do in this emergency is to shut off steam to halt the temperature rise. Unless the vacuum lapse is of long duration, there will be no harm to the massecuite as the grain will remain in adequate suspension for an hour and even longer if mechanical circulation is present.

With cessation of boiling, the oversaturation indication will be lost and certain precautions are in order to bring the pan back into operation safely. When vacuum is restored it would be wise to set the control for an inch or more higher absolute pressure initially and even give the pan a modest drink of water. As soon as vacuum is stabilized, turn on steam gradually to get the pan boiling and the oversaturation indicator back in operation. With these precautions it should be on the low side so that absolute pressure can be slowly brought back to the value that was carried prior to the disturbance. When oversaturation returns to a normal level, feed can be restored to bring values to normal for continuation of the strike.

Intermediate Purity Boiling

Although the good-practice rules of boiling high purity syrups apply, some of them assume less importance in the intermediate grades which include cane B strikes and Beet High Raws. The tendency of crystals to form conglomerate grain drops quite rapidly with purity; crystal faces that touch can be quickly welded together in a high purity medium but a film of impurities can be left under lower purity conditions, giving the faces a chance to be pulled apart by massecuite movement before they adhere firmly. High Raw sugar in a beet factory is generally remelted so the small amount of color carried by imperfect grain is of less importance.

However, nothing is lost by boiling these strikes in the same manner as higher grade ones. Increased yields obtainable from clean grain along with better color can only do good in improving the capabilities of the low grade boiling that follows.

Beet high raw pans in the 85-88 purity range are generally seeded with ground fondant the same as the white pans. Spot checks indicate that the rate of grain growth at maximum oversaturation is not too much lower than in white pans. Cane A pans can be seeded as well and a good footing attained in 20-30 minutes although they are generally started from a footing or seed strike of previously prepared crystals. Even cane B pans in the mid 70 purity range can be seeded successfully although they are traditionally started on a footing of C sugar slurry or by cutting part of an A strike to provide the basis of grain. More of footings later.

Low Purity Syrups

This area is concerned with beet low raw strikes in the 75-78 purity range and cane C strikes running from 60 to 65 purity. For those in the different fields, beet impurities tend to inhibit crystallization and good molasses exhaustion lies in the mid 50 purity range. Cane impurities salt out sucrose and molasses in the very low 30 purities are considered par.

Boiling these low purity syrups poses some entirely different problems than are associated with high and even intermediate purity syrups. For one thing, crystal conglomeration becomes of minor importance although some care is in order to keep it within limits. The crystallization rate of sucrose appears to drop very rapidly with purity decrease in these areas. Massecuite leaving pans must be held in crystallizers to provide time for crystal growth because it is not economically feasible to afford enough pan volume and time to obtain the needed extraction in them.

Improvement in molasses extraction pays good dividends but this is a subject outside of this essay. The work that can be accomplished in crystallizers is limited by the available retention time and by the goodness of their manipulation. We can't change the retention time without more crystallizers but there are ways to do more of the extraction in the pans and effectively reduce the amount of work that must be done in the crystallizers.

The movement of massecuite in a crystallizer apparently is considerably inferior to that which can be achieved in a pan so the crystal growth rate suffers. In addition, oversaturation created in a crystallizer by gradual cooling is not as susceptible to easy measurement as it is in a pan where the material is moving and boiling and continuous oversaturation measurement can be accomplished with relative ease. It seems in order then to explore ways in which increased low purity extraction can be increased in pans before the massecuite is relegated to the less efficient crystallizers.

Low Purity-Seeding

Pans boiling low purity massecuites are generally seeded with fondant sugar but initial grain development is quite slow in impure syrups. There are alternatives;

excessively low purity syrups may be "spiked" with a little high purity syrup to increase crystal growth without much effect on final pan purity since graining volume is relatively low. If a small pan is available it may be charged with reasonably good syrup and be seeded to grow well developed small grain in a relatively small volume to form a basis for the low grade pan. It cannot be over emphasized that good initial grain is needed in any pan if the final product is to be of high quality.

There is a general tendency to use too much seed in low grade pans making the final grain too small to purge well in centrifugals. In continuous centrifugals the screen slots are about 0.005" wide and most crystals smaller than this go through, raising molasses purity. After good boiling practice is established. it is well to reduce the quantity of seed until all available pan time is needed to handle the available syrup. An idle pan is not growing grain. The required amount of well ground fondant slurry should be about 500 ml for a normal pan but more or less may be needed depending on the way seed slurry is prepared. After one pan is boiled and the final grain examined, the seed quantity is easily adjusted to change grain size and boiling time since $1/2^3 = 1/8$ as much seed doubles the crystal size.

Low Purity Boiling

Once seed is introduced and the crop verified by microscope cheek, the oversaturation may be raised to a high (60-65%) level since there is little tendency to form conglomerate grain in low purity syrups; the primary problem is to deposit sugar as fast, as safely possible. Every available trick should be used to this end.

One advantage can be gained by boiling initially at higher temperatures than normally used for low purity pans. At 6" Hg. abs. pans will be in the 80-85^{0}C range, increasing crystallization rate without raising viscosity of the oversaturated syrup.

If feed syrup is heavy, some water feed may be needed to slow the rise of pan level or the pan may be fed syrup for a time and then held on water until the grain "comes together". As the percentage of crystals increases, the consistency set point should be raised in small steps to hold high oversaturation just as in the high purity pan until the crystal yield is 15-20% and a good boiling consistency is reached. The Consistency Monitor reading will be 10 or 15% higher than it was before much grain was present.

Consistency cannot be allowed further increase so, just as in the high grade pans, the increasing crystal area will cause the oversaturation to decline. But this works against the objective of growing as much grain as possible in the pan. So another strategy is called for. With Consistency controlling syrup or water feed, the Oversaturation can be held high only by manipulation of the absolute pressure and corresponding pan temperature. As oversaturation tends to fall, the absolute pressure can be lowered in small increments to keep oversaturation at a safe high level to promote rapid crystal growth in massecuite of proper boiling consistency. This operation is easier than it sounds; one simply notes that oversaturation is below the limit and makes small downward adjustments in absolute pressure, watching the effect on oversaturation.

Eventually, the limit of condenser capacity will be reached; if the pressure can be brought down around 4" Hg. Abs., the pan temperature will be in the mid 60 range and a great deal of sugar will have been deposited with attendant increase of crystal area.

From this point on, absolute pressure and consistency are maintained but oversaturation inevitably falls. The massecuite is in a safe area and the operator can relax until the maximum pan level is reached and feed is shut off. As the pan brixes up the oversaturation will rise and must be watched to be sure it does not exceed a safe limit, but with the falling mother liquor purity and high crystal yield, it can go above the previous 65% limit more than in the higher purity pans. Frequent microscope cheeks for appearance of fine grain on a pan or two will enable determination of the safe oversaturation indication so that succeeding strikes can be fed with a little water if necessary to keep below the safe limit.

By operating a low purity pan in this manner, maximum sugar extraction can be obtained in the pan and clean grain with adequate surface area delivered to the crystallizers which can easily complete the sucrose extraction if properly regulated. Crystallizer operation is, however, a subject outside the scope of this paper.
Final brixing should be carried on to get maximum yield that can be handled in the crystallizer station. In beet sugar operation, a non-sugar/water ratio in the mother liquor at pan drop should be in the neighborhood of 3.0. Cane syrups are less viscous so N/W ratios of 8.0 are not uncommon although insufficient information is available at this time to bracket the acceptable tolerance. If pans are dropped with too low a N/W ratio, crystallizer extraction will be penalized; if too

high, crystallizer drive mechanisms can be overloaded by the high massecuite viscosities during the cooling cycle and it may be necessary to dilute the massecuite to stay within tolerable limits. Even so, recourse to water dilution should be avoided if possible. No less authorities than R. A. McGinnis and T. Moritsugu agree that water is the most melassigenic material that can be added to a crystallizer. Excessive viscosities are better corrected by diluting with pre-spun and deaerated molasses to reduce the crystal-liquor ratio. Figure 3 diagrams the low grade cycle described above.

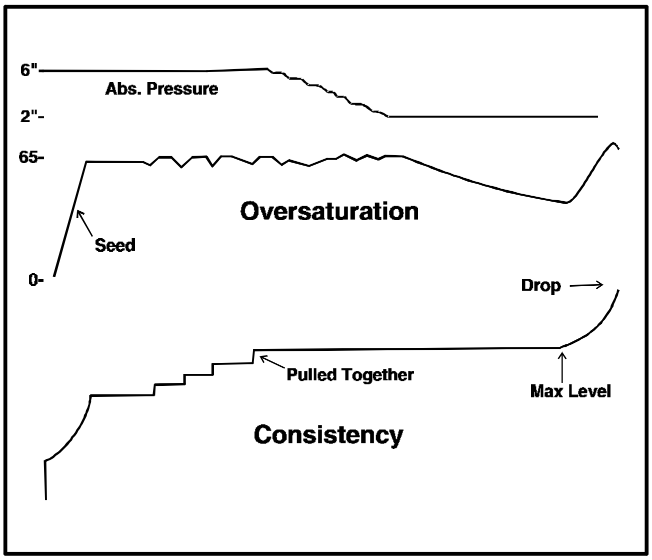

Figure 3
Typical low purity pan cycle.

Large Grain Problems

Boiling normal granulated white table sugar in the 0.014" - 0.020" size is readily done by the methods previously described. The coarser white sugars demanded in Middle East and Asian countries or decorative sanding sugars in the 0.030" and larger sizes require some modification of pan cycles. Raw cane A and B sugars should also be boiled to larger grain for better centrifugal work, holding pol up without excessive washing to reduce impurities contained in the syrup film on crystal surfaces. The affination stations of some refineries are borderline and their capacity is markedly reduced when they must process fine grained raw sugars. So the techniques available for boiling larger grain should be explored.

Given adequate syrup oversaturation measurement, it is not difficult to boil large sized crystals in a pan, but if done in one pass, it is not economical of pan time and utilities. By introducing the required small number of seed crystals and maintaining suitable high oversaturation long enough they can be grown to any desired size but the pan must be kept boiling to provide the circulation necessary to hold them in suspension. This means feeding large quantities of water to stay within the oversaturation limit until sufficient crystal area is created. In the early stages of any strike, a pan is primarily an evaporator and doesn't do much useful work as far as growing sugar crystals; it is only toward the end when enough crystal area is present that most of the crystallization takes place.

But there are various strategies available for boiling larger grain more economically. Unfortunately, most pans cannot be operated with less than about 3rd of their maximum volumetric capacity and this puts a limit on their capability which must be lived with. If a small pan is available, it can be used to prepare a footing of established grain to seed a commercial pan so that larger crystals can be produced while the larger pan is filling. This is common practice and makes more efficient use of the striking pans.

Another method for increasing grain size is to seed a large pan with enough crystals for say five strikes, grow moderately sized grain and drop it to a holding tank from which 20% batches can be drawn to supply the crystal crop for the following five strikes. This way only one pan out of six must be boiled inefficiently on low crystal area.

Cutting Over

In the raw cane industry especially, grain averaging 0.030 to 0.040" is desired and the pan floors are equipped with "cut-over" lines between pans. A strike with double the normal amount of fondant is boiled but not brixed up and half of the massecuite drawn into the second pan. Both are then boiled to completion. The process can be repeated any number of times to produce still larger grain.

Cutting over strikes requires more careful attention than is often provided. Observation of this operation on many pan floors around the world reveals that too often a good "Mother strike" is ruined during transfer and many "Daughter strikes" are badly degraded during the cut-over. A semi-trained sugar boiler feels that he must suck the massecuite into the receiving pan so he applies as much vacuum as he can get to hurry the process. The warm oversaturated massecuite entering the second pan flashes off some vapor which both concentrates and cools it and can easily raise its oversaturation to the point that will bring in a copious quantity of new crystals. And if vacuum is not increased carefully on the original pan, the same thing can occur.

But many sugar boilers have been instructed in proper techniques with most rewarding results. It is perfectly possible to effect a good cut-over without damaging either pan massecuite. It is well to have the "mother" massecuite in the safe 50-55% oversaturation range to give some factor of safety. The receiving pan should then be stabilized at an inch or so higher absolute pressure than was carried in the donor pan. With no steam on either pan, vacuum should be broken on the "mother" pan to provide a pressure drop for massecuite transfer and the cut-over valve opened. When the interchange is complete, apply steam to both pans to get the oversaturation indication operating and bring the absolute pressure slowly down to the level at which it was working prior to the transfer. Then adjust consistency to the previous value, watching oversaturation to stay on the safe side of the limit until both pans stabilize.

Cutting over can be used to advantage in low raw beet syrups to increase grain size and reduce loss of fine grain through centrifugal screens but facilities must be in good order and operator skill maintained at a high level for consistently good results. One bad apple in a barrel can spoil them all and one bad low raw strike in a continuous crystallizer will cut the efficiency of raw end operation for many hours.

This listing of sugar boiling strategies is far from complete but necessarily so because pan floor equipment is so varied. But perhaps it will serve to point out that with suitable measurement of the major variables and an understanding of the physical limitations, it is possible to improve the operation of almost any pan floor.