

# PAN CONTROL, WITH SPECIAL REFERENCE TO OVERSEAS DEVELOPMENTS

By W. O. Christianson and E. P. Hedley.

The vital importance of the vacuum pan station has always been realised, but while the advance of science in sugar production has led to rapid improvement throughout the factory, the pan station is probably the place where progress has been slowest. The reason for this lies in the fact that sugar boiling has been considered mostly as an art, and the sugar boiler naturally was not greatly disposed to having his secrets closely examined. Gradually, however, the principles underlying the operations have become more thoroughly understood, and helped by the constant demand for refiners for better quality raws, the subject has become the object of close scientific investigation.

Refineries require a high polarization raw sugar of good keeping quality, and one which moreover, will not cause trouble in filtering. It was early realised that refinery requirements were met in sugar of fairly large and even sized crystals, which were free from fine grain and occlusions of impurities. The aim of good pan-boiling then, is to make only such sugar as conforms to this specification while at the same time obtaining the maximum possible exhaustion of the mother liquor. The careful work required in the preparation of such a desirable product was originally thought to have as a necessary corollary the slowing down of the output of the sugar factory. Fortunately, overseas experience has shown that far from this being the case, just the reverse has happened. The strict control of pan-boiling demanded has resulted not only in the improvement of the sugar and increase in recovery, but also in increase of output.

Considering briefly what happens during the concentration of a sugar solution such as cane syrup or dilute molasses, we find that the well defined stages common to solutions of many substances are passed through. Starting with the solution in unsaturated and stable condition, concentration makes it first saturated, when it is incapable of dissolving further sucrose, and then it becomes supersaturated and actually holds in solution more sucrose than in the saturated condition. Increase in temperature increases the solubility of sucrose and the degree of supersaturation is lowered by a rise in temperature, a supersaturated solution even becoming unsaturated if the temperature increase be sufficient. In the supersaturated state two successive stages are recognisable, firstly the "metastable" condition in which a shock, such as inoculation by the introduction of crystals, is necessary to induce crystallisation, and a further unstable stage the so-called "labile" state, in which crystallisation will take place spontaneously.

The formation of crystals in a vacuum pan, known as "graining," is therefore accomplished when the liquor is in supersaturated condition. One method is called the "waiting" method in which evaporation is continued into the labile state when spontaneous crystallisation occurs. Another method is the administration of a shock fairly late in the metastable stage by introducing finely divided sugar, allowing air to bubble through the liquor, suddenly lowering the temperature or even by admitting a large charge of less concentrated liquor. Finally there is the method of seeding which is carried out early in the metastable condition by introducing the required number of small crystals in the form of carefully ground and sieved sugar, only these being allowed to grow into the final product. This last method has been found to produce the best results.

Producing grain by either the "waiting" or "shocking" methods naturally takes a certain amount of time, during which new crystals are continuously being formed, resulting in grain of varying size. When sufficient grain has been obtained, further formation is checked by lowering the supersaturation, and the small crystals rapidly grow to regularity of size as do also the small broken crystals introduced in the seeding method. During the early stages of growth of these crystals however the actual absorption of sucrose is very slow, owing to the small crystal area available, so that the degree of supersaturation must be most carefully controlled. Generally speaking, at this stage it is difficult to boil the pan slowly enough while still maintaining circulation of the mass, and so it is now customary to admit very carefully, "movement" or "equalising" water. This gives a fine control of the degree of supersaturation, which would otherwise be increased by the continual loss of water by evaporation. As the grain becomes well established the gradual speeding up of the work of the pan is allowed and increased steam, vacuum and the admission of liquor feed is then used until the pan is finally filled up.

Once the pan contains the required number of crystals, however, the formation of further crops of crystals known as "false grain" must be avoided as far as possible, or if any do form, they must be carefully "washed out" or dissolved by the introduction of water or liquor until the masseculite becomes undersaturated. The presence of false grain is undesirable for several reasons. The packing of these smaller crystals between the larger ones during centrifuging, prevents the ready escape of

molasses, so that excessive washing or steaming is required. The re-dissolving of the sugar thus incurred, together with the actual escape of much of the fine grain through the centrifugal gauze, results in returning back into process sugar which can never be completely recovered again. The dilution of the molasses film which also results, is of course undesirable from the point of keeping quality in raw sugar, whilst the extra time required in purging has the obvious result of slowing down of output. The formation of false grain in the pan is also held to be one of the chief causes of the occlusion of impurities already mentioned.

This occlusion of impurities has been found to be a major cause of poor filtrability as the harmful non-sugars fixed in the crystals cannot be removed by the ordinary affination or purging of raw sugar in the refinery. These occlusions are the concern not only of the refiner but also of the direct consumption white sugar manufacturer, for impurities which cannot be removed from the crystals in the centrifugals permanently discolour his product. Two main types of occlusion are recognised, namely the envelopment within the crystal lattice of particles of colloidal matter which have escaped elimination in the clarification process, and the other type is the inclusion of "pockets" of mother liquor in the growing crystal or in the crevices inside the crystal complexes called "conglomerates." The first of these types of occlusion is the outcome of poor clarification, but the second is the one in which we are now interested, for it is due to faulty pan-boiling.

The trapping of mother liquor within the crystals has been traced to erosion followed by rapid rebuilding of crystals in the boiling, and erosion of crystals will take place whenever a state of under-saturation occurs. This state will be deliberately brought about when it is necessary to wash out false grain, but it may also occur with any sudden increase in temperature. Such an increase in temperature may occur throughout the pan due to fall in vacuum or increase in steam pressure, or it may be purely local and due to poor circulation causing the massecuite to become overheated in the proximity of coils or calandria, another important cause being poor mixing of the incoming feed with the massecuite.

Conglomerates consist of numbers of crystals which have become so closely knit together that they are a fused unit, the parts of which cannot be separated except by actually breaking the individual crystals themselves. These complex units are formed most readily in high purity liquor and so usually occur early in the boiling, but they may be formed at any time if the degree of supersaturation is forced up into the "labile" state, resulting in the formation of false grain which readily knits together.

The presence of fine grain in the molasses feed may be the result of false grain in massecuite from which it was spun, or it may be due to spontaneous crystallisation on storage. It is obvious that this fine grain will have most of the disadvantages of false grain formed during boiling and will require to be removed in the pan itself. The sufficient dilution of the molasses feed is the obvious remedy, and it has been found that the quantity of water required for this purpose can be far less than that required for washing in the pan, with all the attendant disadvantages this entails.

From the above discussion it is obvious that the control of the degree of supersaturation is all-important, and anything which will cause any unexpected variation in it is to be strictly avoided. Upsetting factors are those attendant on sudden changes in vacuum, steam pressure, density and temperature of the syrup or molasses feed, the presence of air leaks and poor circulation in the pan itself. In the control of the supersaturation the pan-boiler has in the past had to rely on his experienced judgement, but any instrument which can give him a more reliable guide under all conditions is obviously an enormous aid. Many instruments have been devised with this aim in view, but experience overseas has shown that the most efficient is that which depends on the measurement of the electrical conductivity of the boiling mass.

It has been found that for all practical purposes the conductivity of syrups and molasses varies in an inverse manner with the concentration. This means that an increase in supersaturation of the mother liquor of a massecuite results in a decrease in conductivity, and a decrease in supersaturation is associated with an increase in conductivity. The instrument is of the recording type, and once a master chart has been prepared for all the operations required in the production of a particular grade of massecuite in any given pan, it has been found to be an easy matter for the skilled pan-boiler to follow this chart, and in duplicating it, reproduce the desired grain quality. Conditions vary from factory to factory and from pan to pan, so it is necessary to emphasise that the best method of working must be established for each pan, and research at each factory is necessary. A microscope on the pan floor is also a great assistance, for it enables the grain to be properly examined at all stages of the boil. Recording thermometers and pressure gauges have also been found to be a decided help and should not be omitted.

There are other important applications of the electrical conductivity instrument. It has been successfully applied in the control of the density of the syrup coming from the evaporator and of the dilution of the molasses feed, in which case it supplants the less convenient hydrometer. Because it is electrical it has been easily adapted and with great success to the automatic control of vacuum

and feed, enabling these to be kept remarkably constant, and preventing the violent fluctuations which are one of the greatest worries in pan boiling. A further use, and one which is most important, lies in the fact that it can be employed to study the circulation in the pan.

As has been pointed out above, poor circulation leads to local overheating and poor mixing, with the dangers which follow the understauration due to these causes. Evaporative capacity is of course limited also by poor circulation. The problem of circulation is one to which very close attention has been paid in recent years and this has resulted in improved design of vacuum pans, particularly the development of the "centre-flow" pan and the "Webre" mechanically-stirred pan. In many cases too, alteration of existing pans which may even result in reducing the area of the heating surface, has been accomplished with most satisfactory improvement in circulation, with all its advantages, including increased output. Increases in vacuum pan station capacity of 30% have been reported through the application of scientific methods to boiling generally, and not the least of these increases is attributable to improvements in circulation.

One important point that arises is that although the use of the instruments mentioned above simplifies the work at the pan station, it must not be thought that their introduction might mean the elimination of the present pan-boiler. The constant attention of the skilled operator is just as essential when using these devices as it was before, and it has been found that provided the pansmen are kept fully informed of everything that is being done, so that they realise that the only object is to aid them in their work, their ready appreciation and keen co-operation is easily obtained.

The successful application of scientific research to sugar boiling has been helped by the demand for high quality sugar, which is met by making a product of uniform grain size, of good keeping quality and free from occluded impurities. This research entails the study of conditions applying to each factory and to each separate pan, and it has led to the adoption of improved methods, the introduction of certain instruments, modification of plant and the closer control of the pan-station generally. At but little cost it is now possible to place in the hands of the skilled pan-boiler apparatus which enables him to consistently produce this desired quality of sugar, to increase the capacity of the boiling and curing stations and at the same time to improve the quantity of sugar recovered.

In view of the value of the improvement obtained in other countries, notably Java, Hawaii and Queensland, by this work, it is hoped that it will not be long before a similar study is inaugurated in the South African Sugar Industry.

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The PRESIDENT: The pan station has been the most neglected station in the factory as regards development of the plant used. This year, however, two centre-flow pans have been installed in two of the smallest factories, Shire and Glendale, so we will have centre-flow pans this next year. But I think something should be done in developing a different type of pan altogether, not with stationary heating elements, but with moving elements. I believe a future development will be continuous boiling in pans. I blame the sugar machinery firms for not taking the matter up more fully when I tried it with an ordinary pan. I think this is a very valuable paper, and should be printed in our Proceedings, I should like to hear your opinions. The paper is now open for discussion.

Mr. BECHARD: At a meeting of the convener's committee, we came to the conclusion that only one practical method could be adopted to deal with the work required and that was to take the most immediate problem in hand, solve that, and move on to the next most immediate. That Committee decided that the most immediate one for the moment was the study of the pan station. Both previous speakers have mentioned that the pan station has been very neglected in the past. It has been more than neglected, it has also been interfered with.

In many cases an existing coil pan has had an extra belt added and then transformed into a calendria pan, without regard to circulation.

The capacity of the heating surface was the only factor considered and the calendria well was usually far too small. We have a pan of this construction with a very constricted well. In it the flow of massecuites going up in the tubes was approximately  $1\frac{1}{2}$  times as big as the flow supposed to go back.

Generally speaking, you reckon round about 25 inches as the most satisfactory boiling vacuum, but this vacuum is considerably diminished by the hydrostatic head of the massecuite, and the temperature is increased at the calendria.

If you add to the poor transmission of heat from steam to massecuite the fact that the temperature of the boiling element has already been increased by hydrostatic pressure at that point, you will see that the temperature of the heating elements has got to be raised fairly considerably, and that will account for the erosion Mr. Christianson has indicated.

For the past two years I have been studying massecuites and it is quite evident that high grade massecuites have of necessity got to be worked on a fairly low super-saturation, and the margin of safety as far as the temperature at our super-saturation point and no saturation is very close.

Very often you get the massecuite coming through the calandria, in many cases reaching under-saturation, due to the increase in temperature, and that causes erosion of the crystal and absorption of impurities into the body of the crystal.

I am not sure that I agree with Mr. Christianson about the formation of conglomerates. I think that their formation also depends on a certain type of impurity occurring in a certain form. We find a long crystal will tend to conglomerate, and that depends very much on the nature of the impurities. For instance, at the beginning of the year you often find crystals are longer than later on when the impurities are increased. Some work has already been done at the Refinery, and elsewhere with the cuitometer, but the pan conditions do not allow us to produce the chart satisfactorily and we are therefore absolutely dependent on the craftsmanship of the pan boiler. We are still going to be dependent on his craftsmanship, but we have never afforded any help whatsoever to the pan boiler, and that help is very badly wanted. In some of the older sugar countries in the world, sugar is sold on sample. The factory manager receives a sample of sugar and is instructed to reproduce such-and-such sugar. The only thing he has got to rely on to produce that sugar is past experience. With sufficient experience of the modern methods there is no reason why any sugar mill in the world should not produce a definite type of sugar when they want to do it.

We have got to obtain firstly, the rate of circulation of the particular pan we wish to study, but until this is done we cannot go any further. In the past pans have been bought on two formulas. One has been square feet of heating surface, and the other has been tons of massecuite. Neither of these formulas are any use whatsoever. We want a pan that will produce such-and-such work under such-and-such conditions and at the least expense of steam. At present owing to poor circulation we have got to use live steam and we lose almost all the calorific value of the steam.

Mr. BIJOUX: In this paper it has been stated that in producing grain by either the waiting method or the shock method, grain is continuously being formed. I do not think that in the waiting method you get grain being formed continuously. With regard to the top paragraph on page 93. starting: "The presence of fine grain in the molasses feed may be the result of false grain in massecuite . . ." etc. I do not think everybody agrees that dilution is the solution of the problem, especially where capacity is restricted. I think heating up the molasses before drawing it into the pan is better. With regard to the cuitometer itself, I think it would be difficult to apply in every factory.

Mr. HAYES: Mr. Chairman, and gentlemen—Really this paper does not call for any criticism. It deals with general, and firmly established principles that should be understood and applied by all concerned with the crystallisation of sucrose. But I should like to emphasise and enlarge on a few of the facts which have been conveniently summarised for you in this memorandum.

In discussing conductivity control, let us definitely squash the misconception that an instrument of this type can be put on any pan, and thereafter be expected to carry on with the good work and produce nice sugar! The upsetting factors mentioned by the writers—sudden changes in vacuum, steam pressure, density and temperature of syrup or molasses feed, the presence of air leaks, and poor circulation — will be encountered on every pan station, and conductivity instruments when first installed will, by the very inconsistency of their working, show quite clearly to the trained and reasoning observer, the paramount importance of first standardising boiling conditions before attempting to lay down standard boiling procedures.

Many people seem to admit these upsetting factors, but are inclined to gloss them over and still expect the instrument to do good work, or at least help a little. It is a vain hope.

Circulation must be as nearly perfect as possible in the pan. In Natal the main fault with our pans is a greediness for heating surface at the expense of the diameter of the centre calandria well. When I met Mr. Duus, he told me that it is now accepted in Queensland that the minimum diameter of the centre well should be 40%—50% of the diameter of the pan itself. I doubt if any of our pans have calandrias even approaching this specification.

Grain in the feed is another serious and frequent deterrent to the boiling of good sugar. It is a popularly held idea among pansmen that it is possible to wash the grain out of a feed syrup by drawing water with it into the pan. The time of contact in the short feed line is almost negligible how-

ever, and from the work at the Refinery it is quite obvious to me that no appreciable removal of grain from the feed is possible in this way, without adding so much water that the crystals already formed in the pan are seriously eroded.

We have had particulars of a Kent "Multelec" instrument for vacuum control, which uses an automatically operated "butterfly" valve on the condenser injection water, as a correction to the actual vacuum variations in the pan itself. It is proposed that this instrument shall be put on trial at the Refinery, and the results obtained will be made available.

A microscope on the pan floor should not be regarded as a luxury. Its regular use is absolutely necessary in the establishing, and running, of any form of conductivity control.

In conclusion may I quote D. L. McBryde, who carried out such a great deal of what must be regarded as pioneer work on conductivity control in Queensland.

"When considered from a theoretical aspect, one can only wonder that a characteristic which is so seriously complicated by the many varying factors which operate within a pan of syrup or massecuite, such as temperature, concentration and viscosity, can possibly serve as a useful and accurate means of controlling the boiling process. It is also surprising that the instrument produces concordant results from juices of widely differing quality and composition and with molasses of varying grades and purities. Suffice it to say that the apparatus will "work," and it apparently leaves little to be desired as a means of process control when once it has been standardised."

I might mention that through the courtesy of Messrs. Duncan Stewart we have at our disposal an excellent working model of a "Herisson" crystalliser. For the time being, this has been installed

for experimental work in the Raw Boiling House of the Refinery, and I hope next year to be able to publish some results.

Mr. DUCHENNE: We have heard about a new instrument for pan control work and I wonder whether any chemist here has any experience of the working of it? It is called the Dittmar-Johnson.

Mr. HAYES: The Dittmar-Johnson is not a conductivity instrument. It works on the transmission of heat from the boiling massecuite to a condensing vessel in the centre flow well of the pan. The temperature of the condensate in that vessel is measured, and the record is used as a measure of the viscosity of the contents of the pan. We had an instrument on trial in the Refinery. I am not prepared to say very much about it, except that we did not have much success with it at the Refinery. The only figures of similar working which we could obtain from the makers were about the raw sugar factory, boiling low-grade massecuites, with pans taking seven and eight hours to boil. We had to apply the same thing to a pan taking one hour twenty minutes to boil. I put our lack of success to the fact that in high purity material the changes in supersaturation were very much quicker and were not so influenced by changes in viscosity as in the low-grade material. The results were definitely not good at the Refinery, but I don't see why they should not work on low-grade massecuite. I believe that the instrument was taken away and tried by one of the factories. I don't know what the results were.

The PRESIDENT: I think you will agree that this paper should be printed, especially the discussion afterwards, amplifying it very much. I am still of the opinion that all the pans should be scrapped. We have got to thank Mr. Christianson and Dr. Hedley for bringing this matter forward, and I wish you to accord them a hearty vote of thanks.

*(Applause)*