

The SeedMaster device

For on-line supersaturation measurement and automatic crystalliser seeding

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Technical summary

Supersaturation is the most important parameter in sugar crystallisation control. Knowledge of supersaturation values is vital during the critical phase of seeding, and in later process stages, if high-quality products are to be produced consistently at the lowest possible cost.

Conventional control of sugar crystallisation, however, generally relies on sensors which provide information on some physical property of the sugar syrup or massecuite, rather than on supersaturation itself. Thus, suggestions found in the literature on the optimal values of supersaturation during a strike are often difficult to put into practice.

Since its introduction in 1984, the completely digital K-Patents process refractometer has become widely used in the sugar industry. In a new development, it is now available with SeedMaster software running in the microcomputer which monitors the refractometer. Thus, on-line measurement of supersaturation and control of automatic seeding in the crystallisers can now be achieved using a single instrument. This paper describes the use and main features of the new system.

Introduction

Crystallisation is a production process whereby the solids content of a solution is crystallised under human (manual) or automatic control. Crystallisation can only take place in liquids (solutions), which are supersaturated.

Supersaturation is the property of the liquid phase only, defined as the ratio of the amount of solids in solution to the amount at saturation. It can generally be achieved either by evaporating some of the solvent, or by cooling the solution.

The value of supersaturation during the different phases of crystallisation is the most important parameter of the



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process. It has a large influence on product quantity and quality (crystal yield, crystal size and size distribution), and also on the cost of production (output/hour and energy consumption). Unfortunately, it is not easy to measure supersaturation reliably and on-line. SeedMaster has been developed to solve this problem and to serve the needs of one of the largest users of crystallisation: the sugar industry. However, it can also be, and has already been, adapted for other crystallisation processes.

Traditional control of sugar crystallisation

One of the most important events in the history of a strike in batch sugar crystallisation is when the supersaturated syrup in the vacuum pan is seeded with a small amount of crystals, or magma. This operation has to be carried out precisely and repeatedly when supersaturation reaches its set-point for seeding, as specified by the sugar technologist. Having completed seeding of the pan it should be carefully controlled to obtain optimal results.

Supersaturation of sugar solutions depends on feed syrup / mother liquor concentration, purity, temperature and quality¹. Traditional instruments in use today, however, measure some other, secondary, property such as an electrical parameter (conductivity, RF resistance and / or capacitance), nuclear absorption (related to density), viscosity / consistency, boiling point elevation or refractive index (related to concentration), microwave absorption, or sound velocity of, or in, the syrup or massecuite.

Although all these parameters are correlated with the critical factor (supersaturation), none of them are identical to it. However, all of the parameters depend on several physico-chemical factors of the syrup or massecuite (e.g. temperature, syrup / mother liquor concentration and purity, crystal content and non-sugar composition). These factors are not directly measured by the traditional devices (with the exception of temperature in some cases) and can not be taken into consideration. On the other hand, with the exception of boiling point elevation and refractive index, all other variables are non-selective, that is they can not be used to measure mother liquor concentration (which has the strongest influence on supersaturation) selectively in the presence of crystals. Therefore, if there is a change in the output of these instruments, it is not known how much of this comes, for example, from changes in concentration, and how much is due to changes in the other variables (crystal content, or non-sugar composition, for example).

Furthermore, in most cases there is no sufficiently accurate transformation mechanism (equation) which could be used to transform measured viscosity, conductivity, capacitance or other data into supersaturation values².

Due to these difficulties, sugar boiling control in use today (as implemented either by the pan-man or by a control system), does not generally involve on-line monitoring or use of supersaturation. In its most advanced form, nuclear density probes, data tables and charts based on solubility data (sometimes outdated) are used to determine the density set-point for seeding in a rather trial and error procedure. Naturally, this procedure can not be used to implement on-line, closed loop control of supersaturation during a complete strike.

The SeedMaster difference

SeedMaster has been developed in a joint effort by K-Patents Oy, Finland,

manufacturer of the PR-01-S process refractometer and Proficon Industrial Controls Ltd., Hungary, a company with long experience in sugar manufacturing and crystallisation control.

With the introduction of SeedMaster it finally became possible to have data on-line, in real time, on supersaturation and to implement reliable, reproducible automatic seeding of vacuum pans by a single dedicated instrument. So, instead of relying on a bare minimum of instruments (manual control), or on traditional devices monitoring substitute factors of questionable value (via either manual or automatic control), supersaturation, the parameter that really counts, can be measured and used to control crystallisation.

SeedMaster relies on the use of a set of equations (a mathematical model) developed to calculate supersaturation on-line, taking into account all of the parameters (see above) which completely specify it. It uses user-selectable data on sugar solubility collected by Grut or Vavrinecz (approved by ICUMSA). This is the most precise model known, tested in real-life applications in several countries.

Syrup / mother liquor concentration and temperature are measured on-line by the well-proven K-Patents refractometer. Feed syrup purity, as determined by the local laboratory should be entered manually using the keyboard of the Indicating Transmitter (IT) of the refractometer. Syrup quality can be characterised by the value of the Wicklund / Vavrinecz saturation function, which depends on the non-sugar to water ratio and several constants (the m, b and c parameters). These constants should be determined by the local laboratory, but if they are not available, typical ones can be entered. Based on these data, the saturation function and supersaturation is recalculated every second by the built-in microcomputer of the refractometer. The results are used to provide the basic features of SeedMaster.

Though the main task of SeedMaster

is to provide help to the pan-man in seeding, or to implement automatic seeding on its own, it can also be used to monitor supersaturation during a complete strike. So, instead of referring indirectly to supersaturation, but having no definitive means of monitoring this crucial parameter, it is now possible to implement precise and reproducible seeding and crystallisation control.

SeedMaster functions

As well as calculating relevant supersaturation data, SeedMaster performs the following vital functions.

- (1) The saturation data are continuously displayed numerically, and trended in diagram form versus time on the LC display of the Indicating Transmitter for local use.
- (2) The data can be used to trigger alarm signals when supersaturation exceeds high set points or drops below the lower limits set by the operator.
- (3) The data are available for transmission as 4 - 20 mA standard current outputs to other equipment.
- (3) The data can be used to implement precise and reliable automatic seeding of vacuum pans by switching on a relay output for a pre-selected time, when supersaturation reaches its selected set-point for seeding.

Though this paper discusses the use of SeedMaster in batch vacuum pans commonly used in the sugar industry, it can be adapted to continuous crystallisers, or cooling crystallisers of the sugar industry, or to the control of crystallisation of other products, for example dextrose.

SeedMaster has been designed to provide the functionality listed above in optional software run by the K-Patents PR-01-S process refractometer microcomputer. All of the original features of the refractometer are left unchanged and, naturally, do not need any authorisation. The SeedMaster software option, however, can be run only on K-Patents refractometer hardware authorised (licensed) to do so. Refractometers already in use can be easily upgraded with the SeedMaster software option.

The authorised SeedMaster software option contains all of the above functionality, even if some of the features are not put to actual use.

The main data display.

The Main Data Display (Figure 1) shows data on supersaturation, set-point for seeding, syrup/mother liquor purity, concentration, and temperature.

Supersaturation versus time is trended in the 0.9-1.5 range with a selectable (10, 20 or 30 minutes/

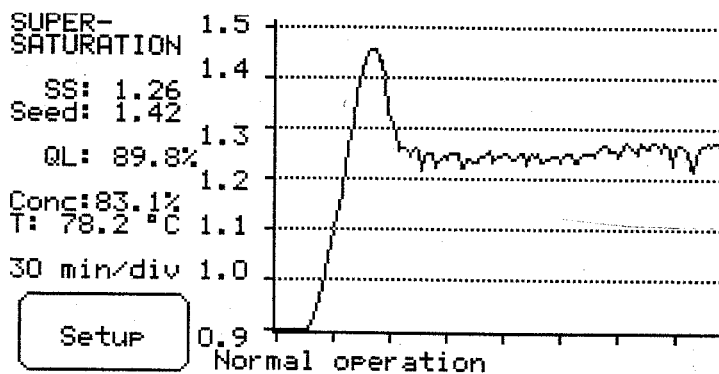


Figure 1. The main data display

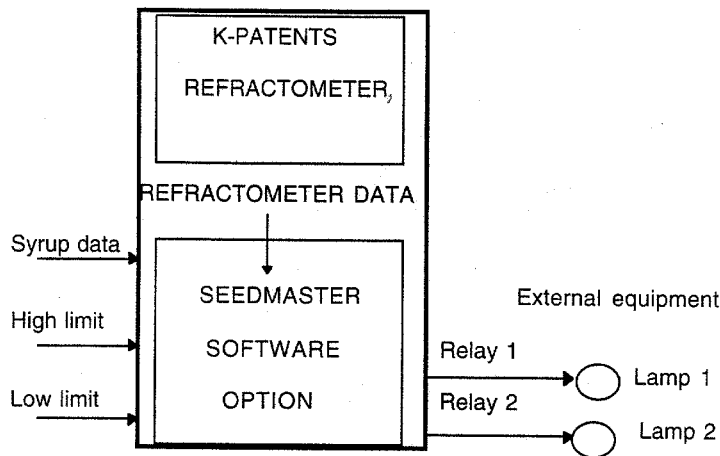


Figure 2. Alarm signalisation and automatic seeding equipment

division) time scale for up to a six-hour strike duration. Selected high and/or low alarm levels are displayed as continuous horizontal lines. Besides the Main Data Display, there are several others used during configuration to specify the different functions and to enter alarm limits, set-point for seeding, syrup parameters and other key features.

External alarm signals

The existence of an alarm signal can be detected on the Main Data Display (Figure 1). Besides this it is possible to light signal lamps, or sound a horn, if a supersaturation alarm has been detected by the program. They can be operated either by the relays of the IT, or by those of the optional Relay Unit of the refractometer (Figure 2).

Transmitting supersaturation data

Calculated supersaturation data can be transmitted as standard 4-20 mA current for further use (for which the External Output Unit option of the refractometer is required). This way, SeedMaster doubles as an intelligent supersaturation transmitter. This output can be used by traditional or paperless recorders (an inexpensive way to document strike

history), or by a data acquisition or control system.

Automatic seeding of vacuum pans

The rate of change in supersaturation can be very fast during the concentration of syrup, therefore reliable and reproducible seeding of the pans can be

achieved only by automatic seeding based on supersaturation data.

SeedMaster is ideally suited to this task. The pan used should have a small vessel mounted on it for the seed slurry (slurry seeding) complete with the seed valve. One of the relays of the optional Relay Unit should be used to operate the seed valve. It is assumed, of course, that the seed vessel has been filled in advance with well-prepared slurry.

In Figure 2, the equipment used for alarm signalisation and automatic seeding is shown. When slurry seeding is practised, one of the relays can be used to open the seed valve for a selected few seconds and to sound a horn at the same time, to confirm that seeding has been carried out. Seeding by magma takes more time, but the relay of the Relay Unit can be used to operate the magma feed valve, too.

Implementation of the automatic seed function requires the use of a switch input of the refractometer to signal the start and end of a strike. If manual seeding is practised, this input should be switched on when seeding of the pan has been completed. The switch input can be controlled by the pan-man, or by the control system in use.

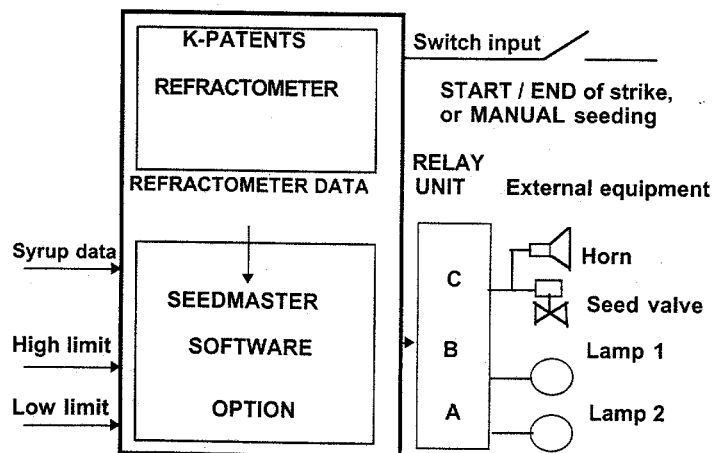


Figure 3. Alarm signalisation and automatic seeding

Typical refractometer specifications

Typical specifications in sugar crystallisation control applications are listed below :

- Sensor material : AISI316
- Sensor length (long probe LPL) : 299 mm
- Connection : Flange
- Prism washing : not needed
- Calibration
 - Concentration range : 65 - 90%
 - Temperature range : 0 - 100°C

Calibration accuracy is vital in providing high accuracy data on supersaturation.

Sensor location selection

Supersaturation depends on, among other factors, the temperature and concentration of the syrup / mother liquor. Crystallisers, however, are not perfectly mixed vessels, which means that depending on the effectiveness of circulation, variations in these parameters can occur.

When measuring some parameter of the massecuite on-line with any type of sensor (density, viscosity or conductivity for instance) the aim is to have reliable data which are representative for the majority of the massecuite. How representative these data will be depends very much on the location of the sensor relative to the syrup feed inlet. This is, therefore a common problem, and the way it is solved will determine to a large extent the usefulness of the data collected.

In Figures 4 A, B and C, three different feed inlet designs and three possible sensor locations (P) are shown. As a rule, the best location is in the pan bottom, if the path from feed inlet to the sensor is long enough to avoid measuring data in a diluted, unrepresentative massecuite volume.

The most favourable configuration is shown in C, where syrup is fed into the pan at several points through a ring pipe under the calandria. This feed design helps circulation in the pan, instead of working against it, as in B.

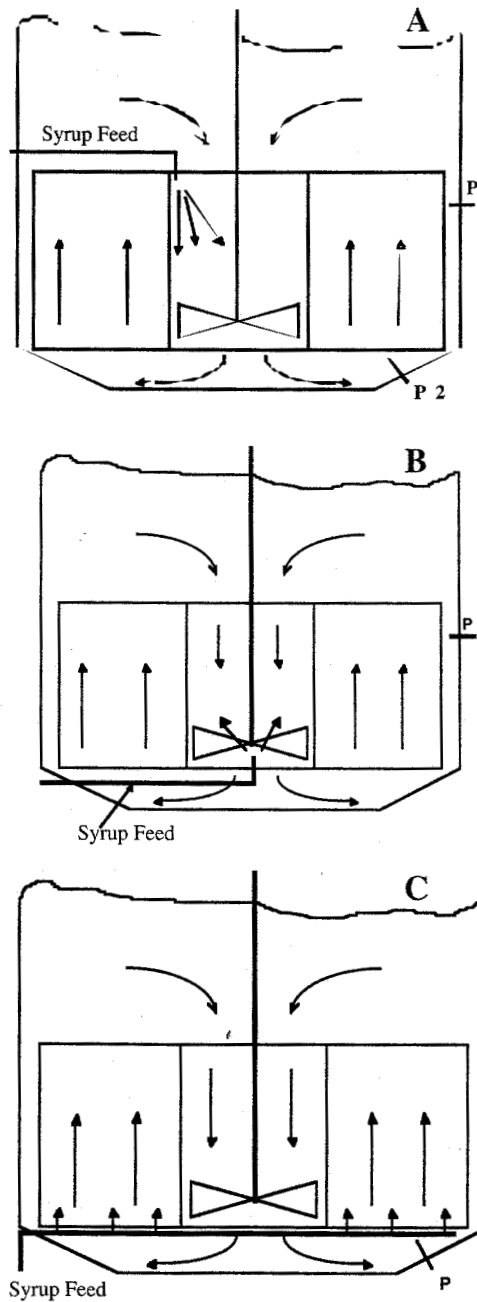


Figure 4. Feed inlet configurations and sensor locations

The sensor should be mounted under the plane of the ring pipe. Fresh syrup moves a full circle, mixing well with the masseuite before reaching the sensor. This takes time, of course, and will result in transport delay, characteristic of every mass transport process. Thus, sensor locations causing the output of the sensor (of any type) to change rapidly when the feed syrup valve opens should be avoided wherever possible.

Conclusion

Sugar crystallisation used to be traditionally considered an art practised by "craftsmen", while nowadays it is more and more taken over by automatic control systems. As we all know, no two "craftsmen" perform in the same way (and even the same individual artisan may make different decisions on the morning and night shifts), and their performance is often unpredictable. Automatic control systems, on the other hand, operate in a quite predictable way (which is why they are being used), but unfortunately, their operation is currently based on the wrong signals. SeedMaster has been designed to provide objective and reliable information on supersaturation to either the "craftsman" pan-man or to the control system in use, and to implement automatic seeding on its own, if required. In one actual application it was shown that due to increased crystal yield and a more favourable size distribution, coupled with decreased steam consumption, the cost of investment (in the refractometer plus the SeedMaster software option) was returned in a mere two weeks time.

Mediciones en línea de supersaturación y siembra automática de cristalizadores (Resumen)

La supersaturación es uno de los parámetros más importantes en el control de la cristalización de azúcar. El conocimiento de los valores de supersaturación es crucial durante la crítica fase de siembra y en las etapas

siguientes, si es que se desea producir consistentemente productos de alta calidad a un costo lo más bajo posible. No obstante, el control convencional de la cristalización de azúcar depende de sensores que proveen información sobre la propiedad física del jarabe de azúcar o masa cocida en lugar de la supersaturación misma. Es así que las sugerencias que se encuentran en la bibliografía acerca de los valores óptimos de supersaturación durante una templa, son difíciles de poner en práctica. Desde el momento de su introducción en 1984, el refractómetro K-PATENTS, completamente digital, está siendo usado extensamente en la industria azucarera. Un nuevo adelanto, el programa SeedMaster instalado en la micro computadora que controla el refractómetro, ya está disponible. Este trabajo describe el uso y las características principales del nuevo sistema.

La mesure en-ligne de la sursaturation et l'ensemencement automatique des cristalliseurs (Résumé)

La sursaturation est le paramètre le plus important dans le contrôle de la cristallisation de sucre. La connaissance des valeurs de sursaturation est essentielle pendant la phase cruciale de l'ensemencement, et dans les phases qui suivent, pour la production constante des produits d'une qualité supérieure à un coût le plus bas possible.

Cependant, le contrôle conventionnel de la cristallisation de sucre dépend, en général, des détecteurs, qui donne de l'information sur une certaine propriété physique du sirop ou de la masse cuite, plutôt que de la sursaturation. Ainsi, les suggestions décrites dans les ouvrages consacrés à ce sujet sur les valeurs optimales de sursaturation pendant une cuite sont souvent difficiles à mettre en pratique.

Depuis son introduction en 1984, le réfractomètre K-Patents, complètement digital, s'est fait employer dans l'industrie du sucre. Suite à un nouveau

développement, il est maintenant fourni du logiciel SeedMaster dans le microprocesseur qui surveille le réfractomètre. Par conséquent, on peut maintenant obtenir la mesure en-ligne de la sursaturation et le contrôle de l'ensemencement automatique dans les cristalliseurs. Cet article décrit l'emploi et les caractéristiques principales du nouveau système.

On-line Supersättigungsmessung und automatischer Aussäung von Kristallisierern (Zusammenfassung)

Die Supersättigung ist der wichtigste Parameter in der Zuckerkristallisierungskontrolle. Kenntnisse der Supersättigungswerte ist während der kritischen Phase der Säung unerlässlich sowie auch in späteren Verfahrensabschnitten, um stets hochwertige Produkte zu niedrigsten Kosten produzieren zu können.

Konventionelle Kontrolle der Zuckerkristallisierung ist jedoch gewöhnlich auf die Sensoren angewiesen, die Informationen einiger physikalischer Eigenschaften des Zuckersirups oder Masseuite geben, lieber als Supersättigung selbst. Deswegen sind die Vorschläge, die man in der Literatur über die optimalen Werte der Supersättigung während eines Streiks findet, schwierig in die Tat umzusetzen.

Seit seiner Einführung im Jahre 1987 wird das komplett digitale K-PATENTS Verfahrensrefraktometer weitgehend in der Zuckerindustrie benutzt. In seiner Neuentwicklung steht es jetzt mit SeedMaster software im Microcomputer, welcher den Refraktometer überwacht, zur Verfügung. Deswegen kann jetzt die on-line Messung der Supersättigung und Kontrolle der automatischen Säung in den Kristallisierern mit einem einzigen Instrument erzielt werden. Dieser Artikel beschreibt die Benutzung und Hauptmerkmale des neuen Systems.

1 Rozsa: *I.S.J.*, 1996, **98**, 660 - 675.

2 Rozsa: *I.S.J.*, 1997, **99**, 263 - 268.