United States Patent

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[54] **CRYSTALLIZATION INSTALLATION WITH CONTROL SYSTEM**

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[63] Continuation-in-part of Ser. No. 804,097, March 4, 1969, abandoned.

[30] **Foreign Application Priority Data**

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[58] **Field of Search** 127/15, 16, 58; 159/44

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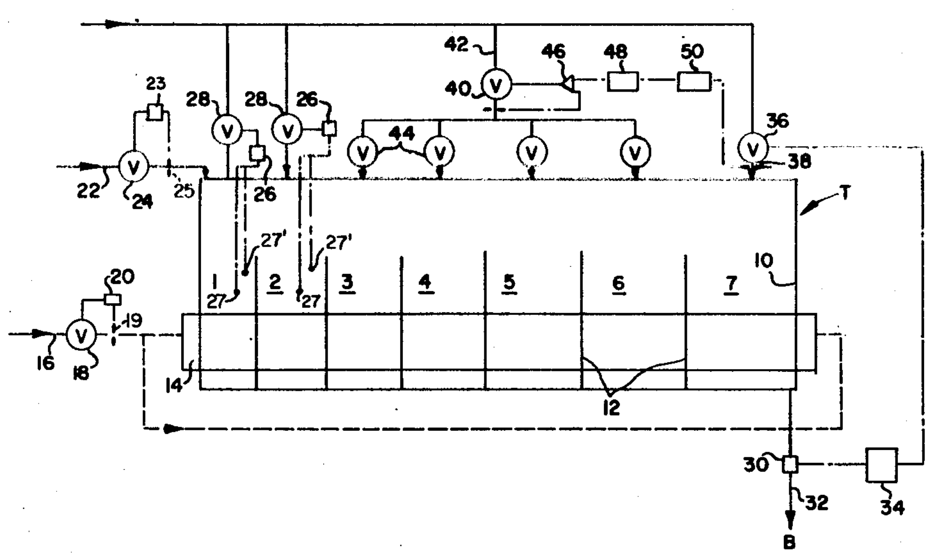
[57] **ABSTRACT**

Sugar is crystallized out of sugar juice by passing the juice through a succession of heated crystallization cells. Diluted sugar juice is supplied to the intermediate cells and the last cell. Either the steam pressure in the heating means or the feed rate of the diluted juice is controlled in response to the percentage of crystals or dry matter in the crystallized product removed from the last cell, the control for the intermediate cells being regulated by an interposed resistance-capacity system which dampens the control signal.

5 Claims, 1 Drawing Figure



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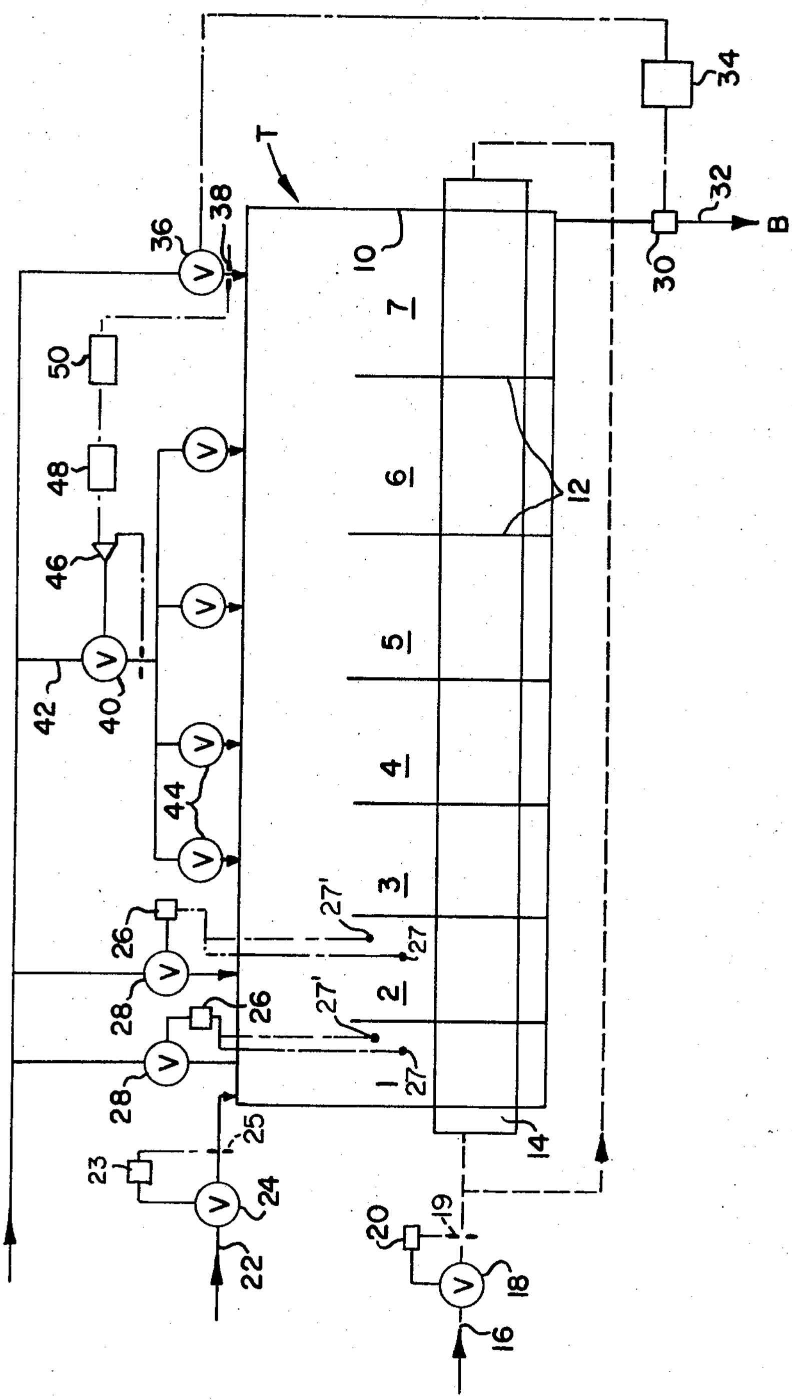

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CRYSTALLIZATION INSTALLATION WITH CONTROL SYSTEM

REFERENCE TO RELATED APPLICATION

This is a continuation-in-part of application Ser. No. 804,097, filed Mar. 4, 1969, now abandoned.

BACKGROUND AND SUMMARY OF THE INVENTION

The present invention relates to installations for crystallizing the solute from a solution, such as sugar from sugar juice, by evaporation of the liquid solvent in a continuous operation, and more particularly to a control system for such installations.

In sugar refineries, for instance, installations for producing sugar crystals from sugar juice include a plurality of successive crystallization cells interconnected for passing the juice to be crystallized successively from a first cell to intermediate cells and then to a last cell. An inlet pipe supplies the juice to the first cell and an outlet pipe removes the crystallized product from the last cell. Steam heating means, such as single or a series of radiators, is arranged in the cells for evaporating liquid in each of the cells, and means is provided for delivering steam to the heating means.

To improve the crystallization conditions, i.e., to increase the percentage of solute crystallized out of the solution and to obtain regular and sufficiently large crystals, it is necessary to control the supersaturation of the solution and the consistency of the treated mass or massecuite at several points during crystallization.

For this purpose, it has been proposed to control the supersaturation of the solution and the consistency or viscosity of the massecuite in successive crystallization cells by supplying thereto metered amounts of undersaturated or diluted solution, or by changing the steam pressure in the radiators in such cells, such control being a function of certain parameters, such as the temperature of the solvent of the solution in the course of the crystallization, its concentration of solid content or solute, the percentage of crystals therein, etc. The feed rate of the diluted product and/or the steam pressure in each cell is then regulated in dependence on the selected parameter.

In accordance with this invention, the control system comprises a first control for regulating the feed rate of the undersaturated solution to the last cell or of the steam pressure in the heating means therein, a measuring element for measuring the percentage of crystals or solute in the crystallized product removed from the last cell, the measuring element producing an output signal responsive to the measured percentage and operating the first control. A second control regulates the feed rate of the undersaturated solution to at least one of the intermediate cells, or a group thereof, or of the steam pressure in the heating means therein, and a resistance-capacity system receives the output signal from another measuring element measuring the feed rate of undersaturated solution to the last cell, which is a function of the output signal of the first-named measuring element, and transmits the same to the second control. The time constant of the latter system increases with the distance of the intermediate cell or group of cells from the last cell.

BRIEF DESCRIPTION OF DRAWING

The above and other objects, advantages and features of the present invention will be more fully understood by reference to the following description of a now preferred embodiment provided to exemplify but not to limit this invention, taken in conjunction with the single FIGURE of the accompanying drawing schematically illustrating an installation according to the invention.

DETAILED DESCRIPTION

Referring to the drawing, there is shown an apparatus for the continuous crystallization of sugar from sugar-containing juice, which includes a horizontally disposed cylindrical tank T sub-divided by partition walls **12** into seven cells or compartments **1** to **7**, any suitable number of crystallization cells being usable, of course. Heating means is provided in each cell, which may take any suitable form, the illustrated heating means comprising a radiator **14** passing through, and common to, all cells.

The heating radiator receives steam through steam feeding main **16**, the steam supply being controlled by a rotatable throttle or butterfly valve **18** in the main **16** which is operated by control element **20** to keep the steam pressure in the radiator at a predetermined value. The valve **18** is actuated by a pneumatic servo motor with a control relay and the servo motor is operated by air pressure regulated by control element **20**, as a direct function of the pressure drop created by a diaphragm **19** placed in the main **16** downstream of valve **18**, this pressure drop being a function of the steam output coming from the valve.

In the embodiment described herein, the product to be crystallized is a sugar-containing juice which has been concentrated in a non-illustrated apparatus and mixed with seed crystals. This mixture or massecuite is fed to the first cell **1** of tank T by feed pipe **22** which carries a double-seated valve **24** for controlling the flow of the mixture into the cell. Valve **24** is actuated by a pneumatic servo motor operated by air pressure regulated by control element **23**, as a direct function of the pressure drop created by a diaphragm **25** placed in the feed pipe **22** downstream of valve **24**, this pressure drop being a function of the output of massecuite coming from valve **24**. The juice and seed crystal mixture then passes to and through succeeding cells through ports in partition walls **12**, and is finally removed from the last cell **7** through outlet B of pipe **32**.

In each cell, a fraction of the juice water is evaporated by the heat produced by the condensation of steam in the radiator, and a fraction of the sugar dissolved in the juice water is crystallized. The concentration of the juice and the percentage of seed crystals is maintained in each cell at desired values by feeding to the cells undersaturated juice whose feed rate is controlled in the manner described hereinbelow.

The feeding of the undersaturated juice to the first two cells **1** and **2** is so controlled that the concentration of the juice is at a predetermined value corresponding to the supersaturation thereof at the temperature of the juice. The concentration of the juice depends on the temperature thereof which is measured in each of these two cells. The undersaturated juice is fed to each of cells 1 and 2 by a double-seated valve 28, each valve being actuated by a servo motor of the same type as that for valve 24, the servo motor being operated by air pressure regulated by control element 26, as a direct function of the difference of the boiling temperature of water and that of the juice, at equal pressures, these temperatures being measured by temperature probes 27 and 27' in the cells 1 and 2. Probes 27 are immersed in the juice and measure the temperature of the juice. The boiling temperature of water is equal to the temperature of the vapor produced in the cells and is measured by probes 27' positioned in the upper part of the cells. As is known, this temperature difference of the boiling temperatures depends on the solute content of the juice. The temperature probes or thermostats 27 and 27' produce an electrical control signal which is applied to the control element 26 by means of an electro-pneumatic converter or transducer. If the measured concentration of the juice in cells 1 and 2 deviates from a set value, control element 26 operates the associated valve 28 so that the feed rate of the undersaturated juice is changed and the two values become equal.

The feeding of the undersaturated juice to the next cells is so controlled that it varies as a function of the percentage of crystals or solute of the product removed from the installation at B.

The percentage of crystals or dry matter in the product is measured in the pipe 32 by densimeter 30 of any suitable and conventional type. The undersaturated juice is fed to the last cell 7 by double-seated valve 36 actuated by a servo motor of the same type as that for valves 24 and 28, the servo motor being operated by air pressure regulated by control element 34 of the same type as element 26, as a direct function of the density of the product leaving the installation at B. In the illustrated embodiment, this density is measured by a gamma-ray densimeter mounted in the output pipe 32, the densimeter producing an electrical control signal which is applied to control element 34 by means of an electro-pneumatic converter or transducer. Valve 36 regulates the feed rate of undersaturated juice to the last cell 7 in such a manner that the percentage of crystals and dry matter is maintained at a desired value.

The total amount of the undersaturated juice fed to intermediate cells 3 to 6 is controlled by double-seated valve 40 placed in a branch feed pipe 42. Additional valves 44 are placed into the individual branchlines feeding each of cells 3 to 6 so that the feed rate to each cell may be regulated in a predetermined ratio.

The main valve 40 for the four cells 3 to 6 is again actuated by a pneumatic servo motor with a control relay, which is operated by air pressure regulated by control element 46 of the same type as element 23, as a direct function of the amount of juice fed into cell 7. A diaphragm 38 in the feed pipe delivering juice to cell 7 produces a control signal proportional to the pressure drop which it creates, this pressure drop being a function of the amount of juice fed into the cell. This signal is transmitted to control element 46 so that the operating signal of the control element is a function of the feed rate of the undersaturated juice to the last cell 7, measured by element 38.

The control signal which regulates the operating signal of control 46 is produced by device 48 to which is applied a signal proportional to the feed rate at cell 7, via a resistance-capacity system 50. The resistance-capacity system may be electric, pneumatic, hydraulic, etc. In the illustrated embodiment, the system comprises an adjustable tap which offers a variable resistance R to the passage of the signal and a capacity C constituted by a closed container. R and C may have any value but the average value of the product of RC, homogeneous at any one time, must be in the neighborhood of 1 hour.

The device 48 produces an output signal which is a linear function of the input signal applied to it so that the output J of the pipe 42 is stabilized according to the equation

$J = aj7 + b$, a and b being constants, and $j7$ being the feed rate of diluted juice to cell 7.

The device 48 is such that the values of a and b may be adjusted as a function of the properties of the product to be crystallized, b having the value zero, if desired.

In effect, the device 48 is an analogue computer. In the illustrated embodiment, wherein the controls are pneumatic, this computer is constituted by a simple diaphragm which may be biased by a spring. One face of the diaphragm is subjected to a pressure p proportional to the input signal and the other diaphragm face is subject to a pressure P whose value is controlled by a valve connected to the diaphragm to permit the pressure P to be increased or reduced as p varies by placing the chamber wherein the other diaphragm face is positioned into communication with a source of air under pressure or with the atmosphere, so that $P = ap + b$. The pressure P constitutes the output signal and serves to control output J of pipe 42.

The resistance-capacity system 50, which transmits the output signal of element 38 to device 48, acts as a low-pass filter. It serves to reduce the speed of variation of this output signal so that the variations of the juice feed rate to cell 7, under the influence of control 36, produce variations in the feed rate in pipe 42 more slowly. The system 50 also serves to dampen the signal coming from element 38, i.e., to reduce its amplitude, when this signal varies rapidly in one sense or the other. This variation is considered rapid when its duration is less than the time constant of the system 50. This time constant is substantially equal to the time required to pass the product through crystallization cells 3 to 7.

While the resistance-capacity system may be electric, the illustrated embodiment comprises pneumatic controls and, thus, the system 50 is constituted by a closed capacity chamber connecting the element 38 and device 48. The output face of diaphragm 38 faces a restricted passage of this chamber, including a constricted opening or venturi, which constitutes the resistance of the system and transmits the varying pressure produced by the diaphragm 38 into a large chamber constituting the capacity of the system, the input face of the diaphragm in device 48 facing this chamber and receiving the pressure therefrom. Like diaphragms 19 and 25, diaphragm 38 is a disc having a central aperture and placed across the feed conduit. The difference between the pressures on either side of the disc indicates the total throughput. The diaphragm in device 48 is non-perforated flexible wall.

Thus, the percentage of crystals or dry matter in the product removed at B is maintained equal to its predetermined value by acting rapidly on the feed rate to the last cell **7** while acting more slowly on the feed rate to intermediate cells **3** to **6**.

Instead of controlling the total feed rate to cells **3** to **6**, each valve **44** could be individually operated by analogous control systems in which the constants a and b, and the time constants are individually adjusted. Similarly, groups of cells may be separately controlled in an analogous manner.

To control the feed rate at cells **3** to **6**, the input or output signal of control **34** may be used, or any parameter proportional to these signals. In this case, the device **48** will be replaced by another device delivering an output signal which is used by control **46** for controlling valve **40**.

It may also be noted that the operation of the installation may be controlled by acting on the steam pressure in the heating means, and such a control may be effected according to the invention by providing separate radiators for each crystallization cell or each group of crystallization cells.

While electric or electronic controls may be used in the installation, pneumatic controls are preferred for this type of crystallization apparatus.

An installation of this type has been operated with a daily output of 365 tons of white sugar, by delivering 8.75 tons of steam per hour to main **16** and 8.75 tons of massecuite per hour to feed pipe **22**. A total of 32.3 tons of unsaturated juice was fed per hour into line **42**, the branch line to valve **28** feeding cell **1** receiving 3 tons per hours, the branch line to valve **28** feeding cell **2** receiving 4.3 tons per hour, the branch line to valve **40** receiving 21 tons per hour and the branch line to valve **36** receiving 4 tons per hour. The hourly output through pipe **32** at B was 32.3 tons per hour.

All the valves and their controls are staple articles of commerce available, for instance, from Societe MECI, Paris, France. Valve **18** is a throttle valve having a maximum steam throughput of 10.7 tons per hour. Valve **24** has a maximum sugar juice throughput of 12 tons/hour and valves **28** have a maximum sugar juice throughput of 4.5 tons/hour for cell **1** and 7.5 tons/hour for cell **2**. The maximum throughput of valve **36** also is 7.5 tons/hour, while that of valve **40** is 40 tons/hour.

We claim:

1. A crystallization installation with a control system, in which the solute of a liquid solvent is crystallized by evaporation of the liquid solvent in a continuous operation, comprising

1. a plurality of successive crystallization cells including a first cell, a last cell and intermediate cells therebetween;
2. inlet means for supplying a solution to be crystallized to the first cell;
3. outlet means for removing the crystallized solute from the last cell;
4. means interconnecting the cells for passing the solution to be crystallized successively from the first cell through the intermediate cells and to the last cell;
5. steam heating means arranged in said cells for evaporating liquid in each of said cells;
6. means for supplying an undersaturated solution of said solute to at least one of said intermediate cells and to the last cell;
7. first control means for regulating the supersaturation and the viscosity of the solution in the last cell;
8. measuring means operable to generate first and second output signals responsive to the percentage of crystallized solute or dry matter in the product in the last cell,
   a. the measuring means operating the first control means as a function of the first output signal;
9. a second control means for regulating the supersaturation and the viscosity of the solution in at least one of the intermediate cells as a function of said second output signal; and
10. a resistance-capacitance system receiving the second output signal from the measuring means and transmitting the same to the second control means.

2. The crystallization installation of claim **1**, wherein the resistance-capacitance system has a time constant at least substantially equal to the time elapsed between the entry of the solution into the first intermediate cell and its flow out of the last cell.

3. The crystallization installation of claim **1**, wherein the measuring means includes a first measuring element for measuring the percentage of crystallized solute or dry matter in the product removed from the last cell, said first measuring element producing said first output signal, and a second measuring element for measuring the feed rate of undersaturated solution to the last cell regulated by the first control means, said second measuring element producing another output signal.

4. The crystallization installation of claim **1**, wherein the first control means regulates the feed rate of the undersaturated solution to the last cell, and the second control means regulates the feed rate of the undersaturated solution to at least one of the intermediate cells.

5. The crystallization installation of claim **1**, wherein the first control means regulates the steam pressure in the heating means in the last cell, and the second control means regulates the steam pressure in the heating means in at least one of the intermediate cells, respectively.

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