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De Villiers et al.

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[54] **COMPARTMENTALIZED VACUUM PAN FOR CRYSTALLIZATION OF SUGAR**

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[52] **U.S. Cl.** .... **127/16;** 127/15; 159/25 R; 159/28 R

[51] **Int. Cl.** **B01d 1/00;** C13g 1/02; C13g 1/00

[58] **Field of Search** .... 127/16, 15; 159/25 R

[56] **References Cited**

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2,160,533	5/1939	Bonath	127/16
2,479,771	8/1949	Parris	127/16 X
3,554,800	1/1971	Javet	127/16
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3,680,621	8/1972	Giorgi	127/16 X

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Assistant Examiner—Sidney Marantz
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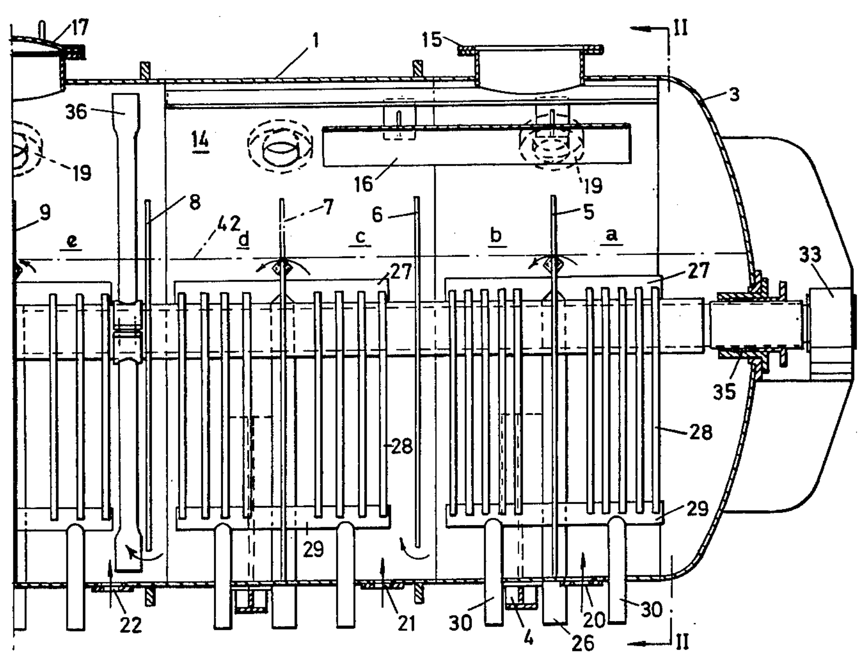
[57] **ABSTRACT**

A vacuum pan for the crystallization of sugar by the continuous boiling of a seeded sugar syrup is made up of a vapor-tight horizontal elongated cylindrical casing divided into compartments by static transverse partitions. Preferably at least seven partitions are used. The compartments all open into a common vapor space running above in the casing, which is evacuated when the pan is operating. The compartment at one end has an inlet for sugar syrup and seed crystals, and the compartment at the opposite end has an outlet for sugar syrup and product crystals. Intermediate compartments preferably have secondary syrup inlets. Alternate partitions have underflow openings and overflow weirs, respectively, by which the syrup and crystals flow from one compartment to the next. Steam-heating means are provided, preferably in the form of steam-fed hollow plates mounted transversely in the compartments. Optionally, there is also a mechanical stirrer for the syrup in the pan.

10 Claims, 3 Drawing Figures



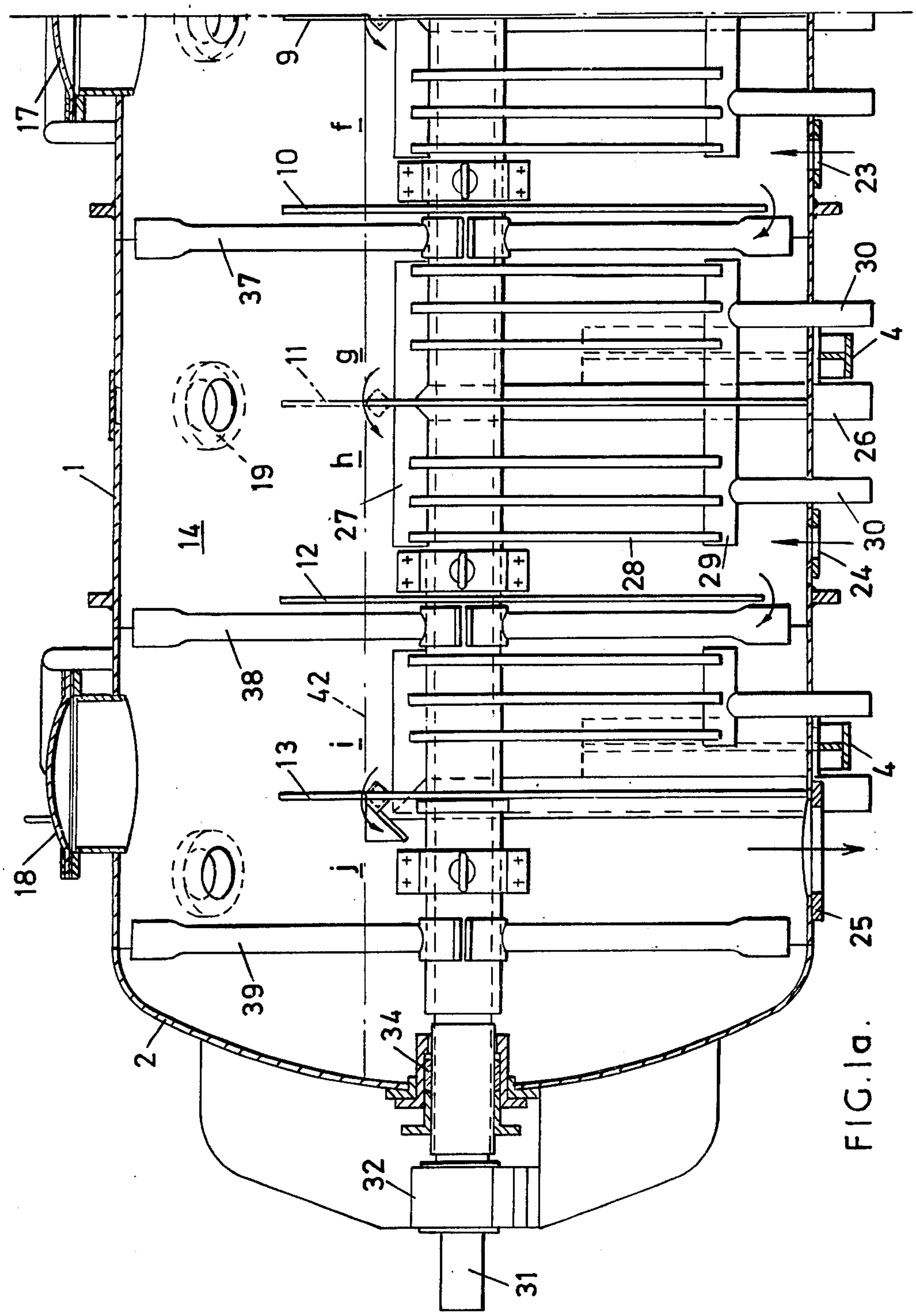

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FIG. 1a.

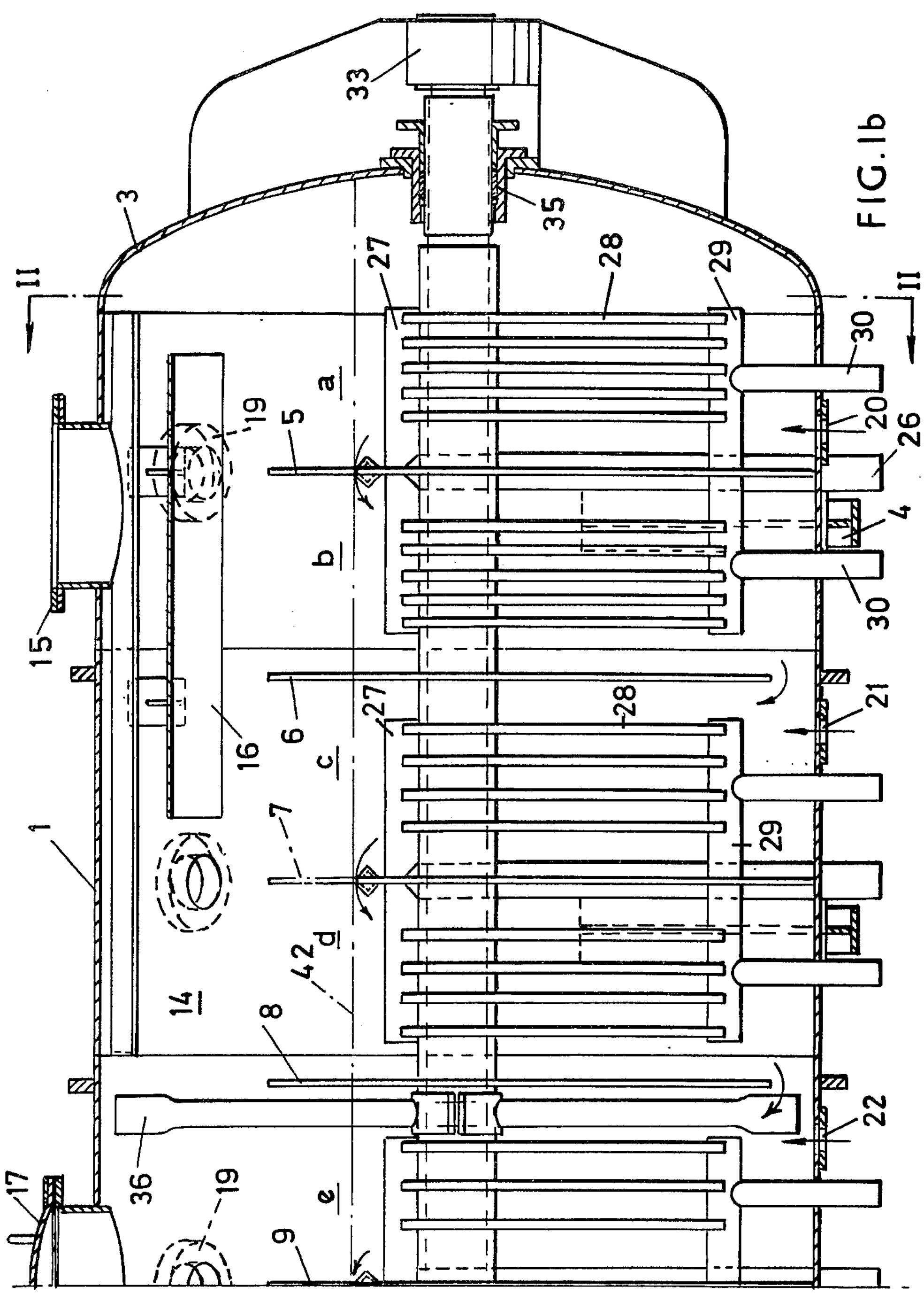

FIG. 1b

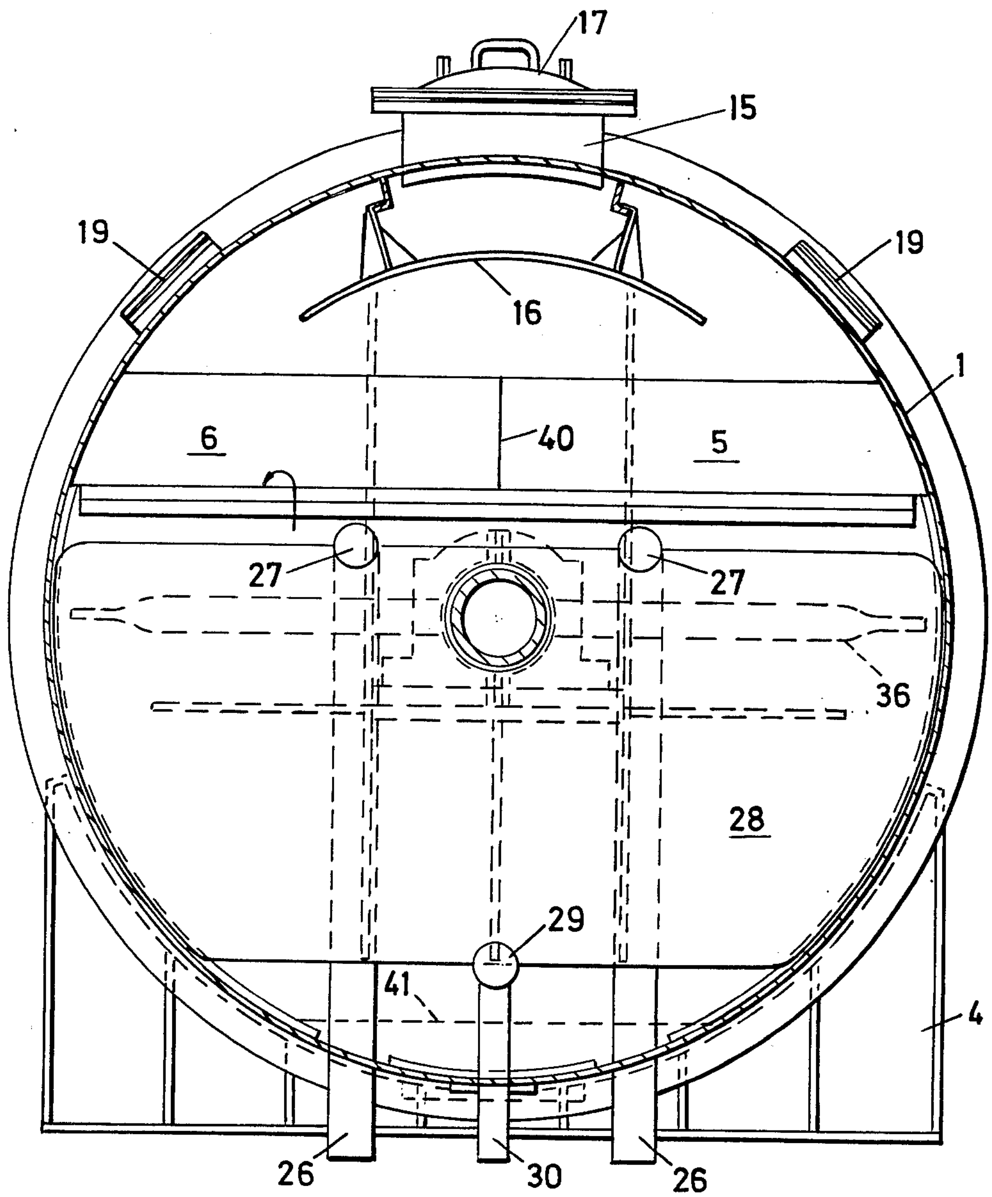

FIG. 2.

COMPARTMENTALIZED VACUUM PAN FOR CRYSTALLIZATION OF SUGAR

BACKGROUND OF THE INVENTION

This invention relates to the crystallization of sugar by the continuous boiling of a sugar syrup.

One stage in the manufacture of both raw and refined crystalline sugar comprises boiling a thick sugar syrup under conditions which promote the growth of sugar crystals therein. Conventionally, the boiling has been performed as a batch process, in vacuum pans. This is subject to the inherent disadvantages of batch operation; and the intermittent feed of sugar syrup and seed crystals, as well as the vacuum and heating, must be carefully supervised by a skilled worker if a satisfactory product is to be obtained.

More recently, various proposals have been made for continuous sugar boiling. However, although the desirability of continuous operation is recognized, the provision of apparatus suitable for this has presented practical difficulties which heretofore have not been entirely resolved. If the sugar syrup is boiled in a single-stage continuous pan, under steady state conditions, the product crystals have a broad distribution of sizes, so that the product must be subjected to classification. Moreover, the crystals are liable to contain a significant amount of impurity, because the whole of their growth has taken place in a solution whose concentration of impurity corresponds to the initial concentration of impurity and the final crystal yield. The use of a single-stage continuous pan is therefore generally unsatisfactory.

The disadvantages of a single-stage continuous pan can theoretically be alleviated by the use of a multi-stage system, provided by a number of discrete pans connected in series, or by a single pan divided into a number of compartments, or by a combination of the two. For instance, British Pat. Specification No. 970,654 discloses the continuous boiling of sugar in a number of stages connected in series, the saturation of sugar syrup flowing from each stage to a subsequent stage being maintained constant by varying the flow rate of heating vapor, the absolute pressure and the amount of thickened juice added to each stage. This process is preferably performed by using conventional vacuum pans in series with a scroll pan, the latter comprising a cylindrical casing containing a tightly-fitting scroll blade which is slowly rotated to provide positive displacement of the material through the pan. U.S. Pat. No. 2,160,533 discloses an apparatus for continuously crystallizing solutions by evaporation or cooling, comprising a crystallizing trough fitted with a hollow rotary shaft on which are mounted hollow sector plates through which cooling water is passed; and the trough is also provided with a screw conveyor, for moving the material through the trough. Rotary means for moving the syrup through the apparatus are also provided in British Pat. Specification No. 527,992, which discloses a continuous pan divided into compartments by a set of discs fitted on a rotating shaft, the compartments being interconnected by openings in the discs. U.S. Pat. No. 2,587,293 describes a multi-compartment apparatus for the continuous crystallization of sugar, in which the pressure is individually controlled in each compartment, and the sugar syrup flows forward through compartments maintained at a successively higher vacuum. Other designs have also been proposed in which the sugar syrup flows downwards under gravity through a series of pans or compartments, for example as described in German Pat. No. 1,188,518 and Austrian Pat. No. 215,923.

The previous designs suffer from a number of disadvantages. Those which utilize several discrete pans, or which require individual control of the pressure within the compartments in a single pan, involve undesirable complications in apparatus and control systems. The pans in which the sugar syrup is moved through by a scroll or similar rotary means suffer from the disadvantages of having massive moving parts, and it is difficult to provide adequate control over the crystallization rate in the individual parts of the pan. In some designs, there is insufficient division between compartments, and these tend to suffer from the same disadvantages as single-stage continuous pans; whilst, on the other hand, too great an isolation between compartments makes it difficult to achieve proper flow of the syrup through the pan. None of the previous designs combine simplicity of operation with a sufficient flexibility of design to cope with different grades of sugar syrup and, in particular, to permit the successful continuous boiling of high-viscosity low-purity syrups, from which it is most difficult to obtain a satisfactory crystalline product.

BRIEF DESCRIPTION OF THE INVENTION

It is an object of the present invention to provide a continuous pan of novel design which overcomes or alleviates the aforementioned disadvantages. Another object is to provide a pan which combines simplicity of operation and ease of control with a sufficient flexibility to make it suitable for different grades of sugar syrup, including high-viscosity low-purity syrups. A further object is to dispense with the rotary means for displacing the sugar syrup through the pan, used in many previous designs, thus greatly simplifying the construction and operation of the pan. A still further object is to provide a pan giving a better approximation to plug flow of material through it than comparable previous designs, thus reducing the spread of residence times for the material flowing through the pan, and hence resulting in a crystalline sugar product with a smaller spread of sizes.

In accordance with the invention, there is provided a vacuum pan for the continuous boiling of sugar, comprising, in combination:

a vapor-tight generally cylindrical casing of length greater than diameter, having its longitudinal axis substantially horizontal;

a series of static partitions within said casing, perpendicular to the longitudinal axis thereof and extending to a height intermediate between that of said longitudinal axis and the top of the casing, said partitions defining a plurality of open-topped compartments communicating with a common vapor space extending above them within the casing;

inlet means for ccontinuously introducing sugar syrup and seed crystals into the compartment nearest one end of the casing, and outlet means for continuously withdrawing sugar syrup and product crystals from the compartment nearest the opposite end of the casing;

communication means for sugar syrup and crystals between adjacent compartments comprising, respectively in alternate partitions of the series, underflow openings located at the bottom of the partitions and overflow weirs at the top of the partitions, whereby the sugar syrup and crystals are constrained to follow a tortuous path when flowing through the pan between said inlet and outlet means;

evacuating means communicating with said vapor space, for removing vapor therefrom and for maintaining a reduced pressure therein;

and steam-heating means for heating the sugar syrup and crystals inside the pan.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The pan of the invention generally contains an odd number of partitions. Preferably at least seven partitions are used, and more often at least nine. Since the casing of the pan of substantially circular cross-section and its longitudinal axis is substantially horizontal, the partitions consist of vertical discs fixed transversely inside the pan, with a minor segment missing from the top of each disc along a horizontal line, so as to provide the common vapour space extending above the compartments throughout the length of the pan. Additionally, in order to provide the specified flow pattern through the pan, alternate partitions are provided, respectively, with underflow openings and with overflow weirs. The shape and dimensions of these means of communication between adjacent compartments can to some extent be varied to suit the nature of the sugar syrup for which the pan will be used, so as to provide the desired degree of ease of flow between compartments. However, the underflow openings normally consist of minor segments cut along a horizontal line across the bottom of the appropriate partitions. The overflow weirs can correspondingly be provided by portions cut along a horizontal line across the full width of the other partitions, so that alternate partitions in the series are shorter than the others. However, it is preferred to provide the overflow weirs in the appropriate partitions on just one side of the partition, and to alternate the side used along the series of partitions. In this way, there is lateral as well as vertical alternation in the communication means between the compartments, thereby providing better flow characteristics for the syrup and crystals through the pan. In this preferred form of construction, the top of each partition extends to the same height in the pan, at a level intermediate between the longitudinal axis of the pan and the top of the casing, but alternate partitions have a portion cut away at the top on one side of a vertical centre line through the pan, so as to provide the overflow weirs.

In order to minimise splashing of massecuite (i.e. the mixture of syrup and growing crystals) from one compartment to another, a possible cause of false grain generation, the dividing partitions should extend to a substantial height above the surface of the massecuite, say 2 feet. The overflow weirs must, of course, be at massecuite level, and sufficient clearance must also remain above the tops of the partitions to allow unimpeded flow vapour. Forward transfer of splashed materials is particularly undesirable, so it may sometimes be preferred for those parts of the partitions which are above the massecuite level to be tilted towards the input end of the pan. Provision can be made to control automatically the working level of the massecuite in the pan, by per se known means such as a level-sensing device inside the pan controlling pumps connected to the syrup inlet and/or outlet.

The steam-heating means may assume various modes of construction. For example, the partitions can be of a double-walled hollow construction and steam fed to them, as well as to a jacket around at least the lower parts of the pan casing. This jacket can be subdivided into sections, so that each section corresponds to a compartment of the pan and communicates directly with the steam space inside one of the partitions bounding that compartment. However, in order to provide a greater area of heating surface, and to improve the heat transmission to the massecuite inside the pan, the steam-heating means preferably comprise a plurality of spaced-apart hollow heating plates inside each compartment, fed from a steam manifold. The heating plates will normally be similar in shape to the partitions but slightly smaller, and will be parallel to the plane of the partitions. The heat supplied to each compartment can be individually controlled by providing separate steam inlets, manifolds and condensate outlets for each set of heating plates within any one compartment; but in practice it is found that a satisfactory degree of control can be achieved if the sets of plates in adjacent pairs of compartments are connected together through common manifolds.

Preferably, the ratio of the working volume within the pan to the area of the heating surface is in the range of from 0.35:1 to 0.4:1. It is also preferred that the ratio of working volume to heating surface within each individual compartment should increase progressively from the input to the output end of the pan. This could be achieved by maintaining a constant heating surface area in all the compartments and progressively spacing the partitions further apart, so as to increase the working volume of the compartments progressively towards the output end of the pan. However, in the preferred mode of construction, the spacing of the partitions is kept constant throughout the pan, and the desired change in the volume to heating surface area ratio is achieved by progressively reducing the heating surface area towards the output end. When using the aforementioned preferred construction of heating means, consisting of a series of spaced-apart transverse heating plates, this reduction in heating surface area can readily be obtained by providing fewer heating plates in the compartments at the output end than in the compartments at the input end of the pan. For example, the compartments nearest the input end may each contain five heating plates, intermediate compartments may contain four heating plates, and the compartments nearest the output end may each contain three heating plates.

It will be appreciated that the construction of the pan of the invention provides a large degree of design flexibility for such features as the working volume of the compartments, heating surface area, and syrup flow rate. Since the movement of the syrup through the pan does not depend on any rotary displacement means, such as a rotating scroll, the space in the compartments is free for the provision of efficient heating means such as the aforementioned transverse plates. Moreover, the steam flow to the plates in each compartment, or pair of compartments, can be individually controlled by means of suitable valves. The steam flow to the compartments can be monitored by measuring the condensate from the heater outlets, so as to maintain the heating to each compartment at the desired value.

Besides permitting a good flow pattern of the massecuite through the compartments, the arrangement of transverse heating plates also gives rise to convection currents which provide a desirable degree of circulation within each compartment. In some cases, this circulation, promoted by the heating elements, is adequate for the syrup being boiled, and it is not necessary to provide any separate stirring means. In other instances, such as when boiling a high-viscosity syrup, it may be necessary to provide a mechanical stirrer to promote the circulation of the massecuite within the pan, especially in the compartments at the "heavy" outlet end. Such mechanical stirring means suitably comprise an externally driven rotary shaft running along the longitudinal axis of the pan through holes in the partitions and heating plates, supported by bearings at either end, carrying radial stirrer arms located within one or more of the compartments. Such a stirrer is caused to rotate quite slowly when the pan is in operation, say at a speed of 1 to 3 revolutions per minute.

The vapour space extending along the length of the pan above the level of the partitions is provided with a vapour outlet communicating with means for reducing the pressure inside the pan to the working value. Such means are conventionally used for vacuum pans and are well known in the sugar boiling art.

In operation, the compartment at the inlet end of the pan is fed with sugar syrup and seed crystals. In accordance with normal practice, the pan feed is usually via an evaporator, in which the solids content of the syrup is raised to about 80 percent by weight. The feed is normally mixed with seed crystals before entering the pan; but, alternatively, seed can be added separately to the first compartment. The seed is preferably dry icing sugar, sieved to a size of 40 – 50 microns; this size is sufficiently large to be safe from dissolution when slurried in saturated syrup outside the pan and then pumped to the first compartment. Dosing of the seed into the feed syrup can be accurately performed by means such as an auger feeder.

Apart from the primary syrup feed to the first compartment in the pan, it is generally preferred also to provide secondary feeds of syrup (but not of seed) into one or more intermediate compartments. The various feeds can be independently controlled, as desired, by suitable pumps in the conventional manner. In this way, the massecuite composition in various parts of the pan can be adjusted for optimum conditions of crystal growth, and the flexibility of operation of the pan is further increased.

The continuous pan of the invention is especially suitable for use with low-purity raw sugar syrups from which some sugar has already been crystallized, such as "B molasses" which typically has a purity of about 70 percent by weight on solids. The pan can also be used for recovery work in a refinery, with a feed of "second crop" liquor, which has a similar purity. However, the pan is also suitable for the continuous boiling of other grades of sugar syrup.

The principal parts of the pan, such as the casing and partitions, can be fabricated from conventional materials, such as mild steel. The heating surfaces within the pan can be made of copper, to achieve better conductivity.

The pan of the invention will be further described with reference to the accompanying drawings, wherein:

FIGS. **1***a* and **1***b* show a sectional elevation through a typical embodiment of the pan of the invention; and

FIG. **2** shows a cross-section through the same pan, along the line II—II in FIG. **1***b*.

The pan illustrated in the drawings comprises a generally cylindrical casing **1** having domed ends **2** and **3.** The casing is supported with its longitudinal axis horizontal by means of the cradles **4.** The interior of the pan is divided into compartments *a* – *j* by means of the vertical partitions **5** – **13,** mounted at right-angles to the longitudinal axis of the pan. Partitions **5, 7, 9, 11** and **13** have overflow weirs, so as to maintain the massecuite level in the pan at a height indicated by the line **42.** The overflow weirs are cut in only one half of the width of each of these partitions, and alternate from side to side along the series of partitions. Thus, the communication between compartments *a* and *b* is provided by a weir on the left-hand side of partition **5,** as viewed in FIG. **2,** indicated by the line **40.** The communication between compartments *c* and *d* is provided by a weir in the right-hand side of partition **7** (as the pan is viewed in FIG. **2**), and so on.

The alternating partitions, **6, 8, 10** and **12,** are provided with underflow openings through which the massecuite can pass. Thus the communication between compartments *b* and *c* is provided by the opening at the bottom of partition **6,** indicated by the line **41** in FIG. **2.**

The compartments *a* – *j* all open into a common vapour space **14,** running along the length of the pan. This space communicates with the vapour duct **15** which, in operation, is connected to means for reducing the pressure inside the pan (not shown). A baffle plate **16** is suspended under the vapour outlet, to prevent splashing of massecuite into the outlet.

The casing is also provided with man-holes **17** and **18,** which are kept sealed during operation. Sight-glasses **19** are provided at intervals along the casing, to permit inspection of the contents of the pan during operation.

An inlet **20** is provided for feeding sugar syrup and seed crystals to compartment *a* of the pan; and an outlet **25** is provided for withdrawing sugar syrup and product crystals from compartment *j*. Additional syrup inlets **21, 22, 23** and **24** are provided for feeding syrup into the intermediate compartments, *c, e, f,* and *h*, respectively; though these additional inlets need not all be used simultaneously.

The compartments *a* – *i* are all provided with steam-heating means, comprising a plurality of spaced-apart hollow heating plates **28,** between which the massecuite can flow. Steam is fed to the plates by the inlets **26** and the manifolds **27**; and the spent steam flows out via the manifolds **29** and the condensate outlets **30.** The heating plates in the pairs of compartments *a* and *b, c* and *d, e* and *f,* and *g* and *h*, respectively, are fed from common manifolds; but this arrangement could be altered, to provide separate steam feeds to each compartment, if it were desired to control the heating in each compartment individually.

In order to provide the desired increase in the ratio of working volume to heating surface area from the inlet to the outlet end of the pan, the number of heating plates **28** decreases progressively through the pan. Thus, compartments *a* and *b* each contain five plates, compartments *c* and *d* each contain four plates, and compartments e, f, g, h and i each contain three plates.

A rotary shaft **31** along the longitudinal axis of the pan is supported externally by the roller bearings **32** and **33**, and pass through the domed ends of the pan via the glands **34** and **35**. The shaft carries stirrer arms **36**, 37, 38 and **39**, located respectively in compartments e, g, i and j. In operation, the shaft **31** is rotated slowly by external means (not shown) and the stirrer arms facilitate the circulation of the massecuite in the compartments towards the outlet end of the pan.

The pan illustrated in the accompanying drawings would typically have a diameter of about 8 feet and a length of 20 – 25 feet. Such a pan would be capable of producing an output of about 180 cubic feet per hour of total crystal and molasses, with a mean residence time of 210 – 240 minutes, corresponding to a working volume of 630 – 720 cubic feet. For the preferred volume to heating surface area ratio of 0.35:1 to 0.4:1, such a pan correspondingly has a total heating surface area of some 1,575 – **r**,060 square feet. The heating plates in the pan will typically be supplied with steam at a temperature of about 98°C, and the massecuite in the pan will typically have a mean temperature of about 75°C. The pan is operated under a vacuum of about 21 inches of mercury. Under these conditions, the pan can be fed with a second crop syrup and seed crystals of 40 – 50 microns size, and will yield product crystals having a mean size of about 0.35 mm. The product crystals are of good crystallographic quality, and the spread of crystal sizes is comparable to that obtained from a batch pan operated under skilled control.

We claim:

1. A vacuum pan for the continuous boiling of sugar, comprising, in combination:

a vapor-tight generally cylindrical casing of length greater than diameter, having its longitudinal axis substantially horizontal;

a series of static partitions within said casing, perpendicular to the longitudinal axis thereof and extending to a height intermediate between that of said longitudinal axis and the top of the casing, said partitions defining a plurality of open-topped compartments communicating with a common vapor space extending above them within the casing;

inlet means for continuously introducing sugar syrup and seed crystals into the compartment nearest one end of the casing, and outlet means for continuously withdrawing sugar syrup and product crystals from the compartment nearest the opposite end of the casing;

communication means for sugar syrup and crystals between adjacent compartments comprising, respectively in alternate partitions of the series, underflow openings located at the bottom of the partitions and overflow weirs at the top of the partitions, whereby the sugar syrup and crystals are constrained to follow a tortuous path when flowing through the pan between said inlet and outlet means;

evacuating means communicating with said vapor space, for removing vapor therefrom and for maintaining a reduced pressure therein;

and heating means for heating the sugar syrup and crystals inside the pan.

2. A vacuum pan according to claim **1**, wherein said casing contains at least seven of the said partitions in the series.

3. A vacuum pan according to claim **1**, wherein said overflow weirs are cut in only one-half of the width of the respective partitions and their lateral position alternates along said series of partitions.

4. A vacuum pan according to claim **1**, wherein said heating means comprise a plurality of spaced-apart hollow heating plates within said compartments and parallel to the plane of said partitions, fed from a manifold.

5. A vacuum pan according to claim **4**, wherein the ratio of the working volume within the pan to the total heating surface area of said heating means is in the range of from about 0.35:1 to 0.4:1.

6. A vacuum pan according to claim **4**, wherein the ratio of working volume to heating surface area within individual compartments increases progressively between the compartment having said inlet means and the compartment having said outlet means.

7. A vacuum pan according to claim **1**, additionally comprising an externally driven rotary shaft located along said longitudinal axis of the casing and carrying radial stirrer arms located within at least one of the said compartments.

8. A vacuum pan according to claim **1**, additionally comprising inlet means for introducing sugar syrup into at least one of the compartments intermediate between those nearest the end of the said casing.

9. A vacuum pan according to claim **1** wherein said heating means are steam heating means.

10. A vacuum pan according to claim **1** wherein there are an odd number of partitions.

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