Dec. 31, 1968 TOSHIO NIWA ET AL 3,419,148

CONTINUOUS-TYPE CENTRIFUGAL MACHINE

Filed Oct. 23, 1967 Sheet 1 of 4

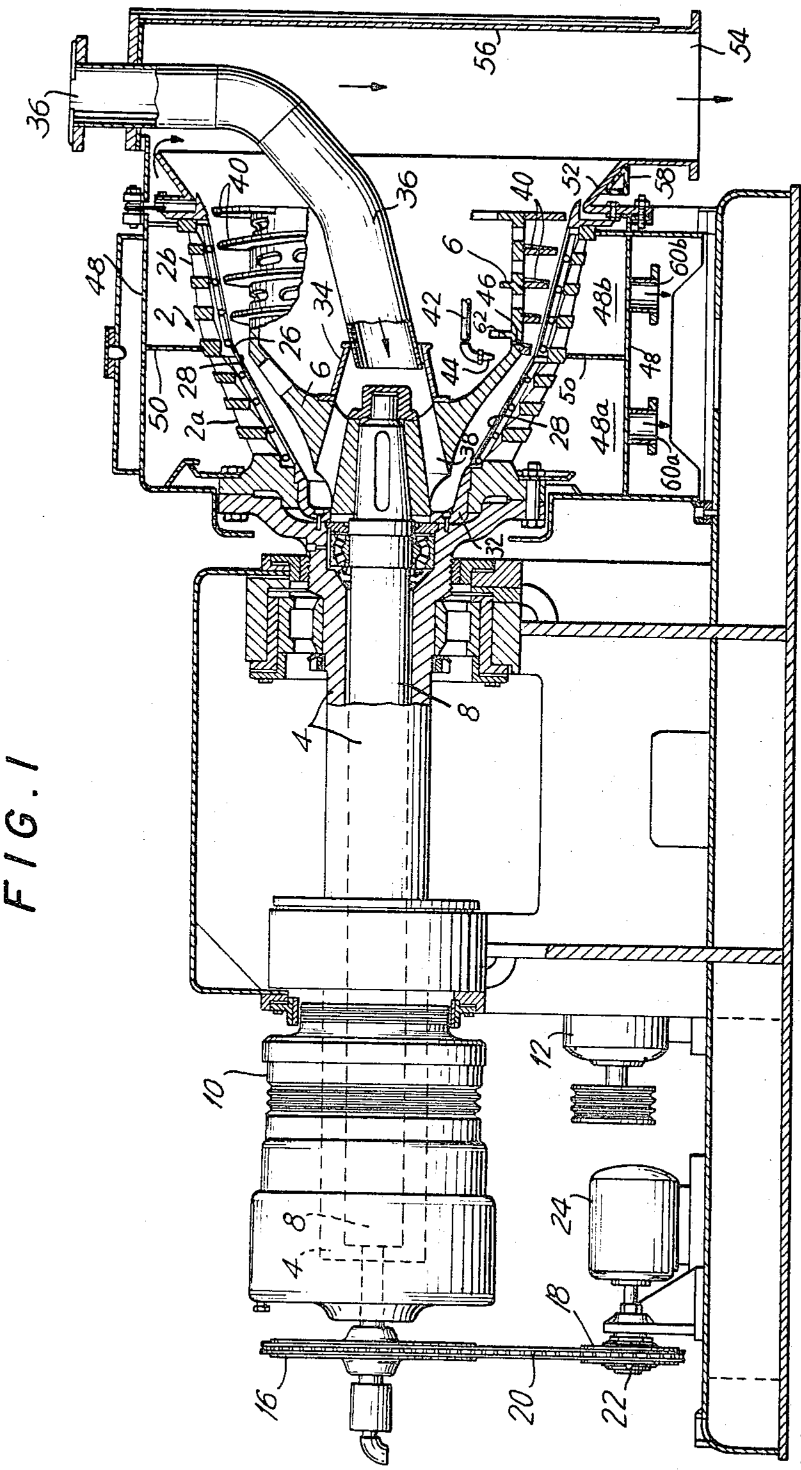

FIG. 1

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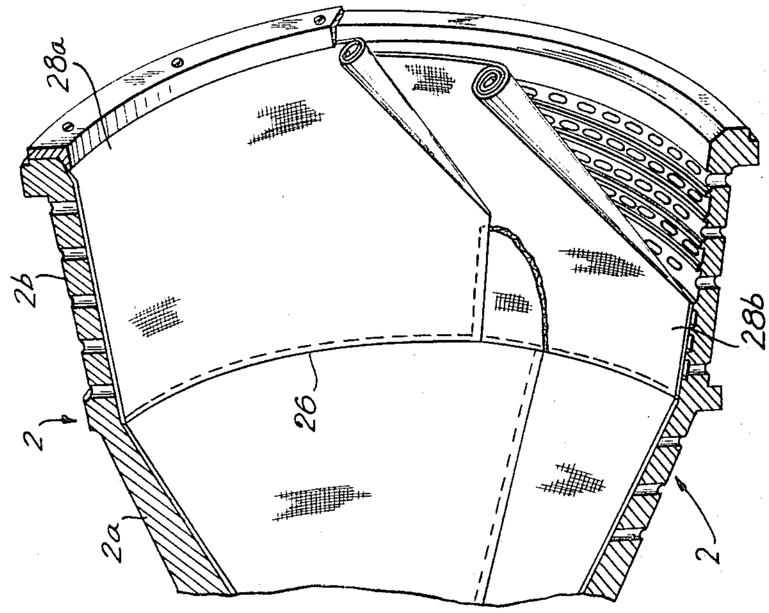
F I G. 3



F I G. 2

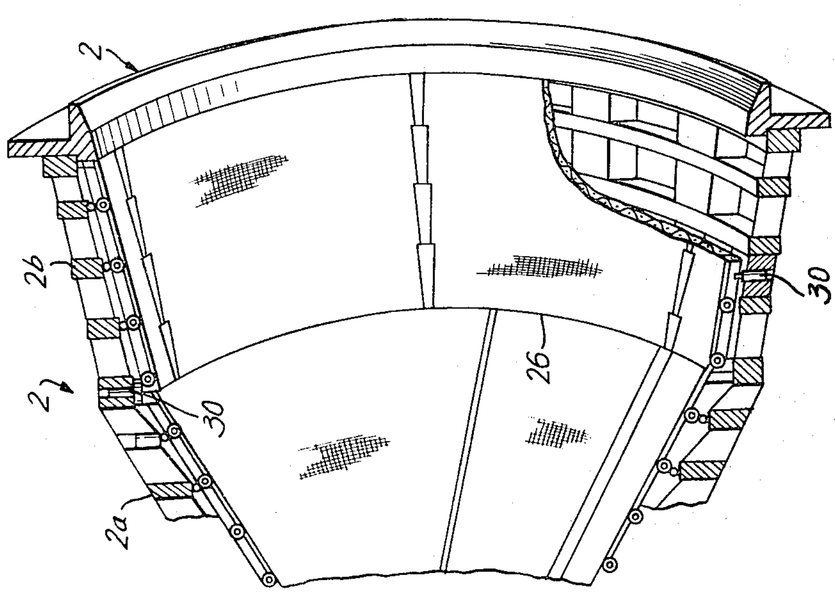


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FIG. 4

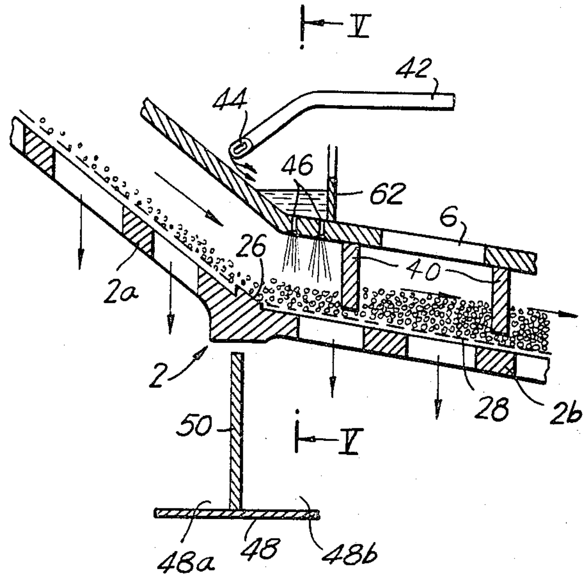
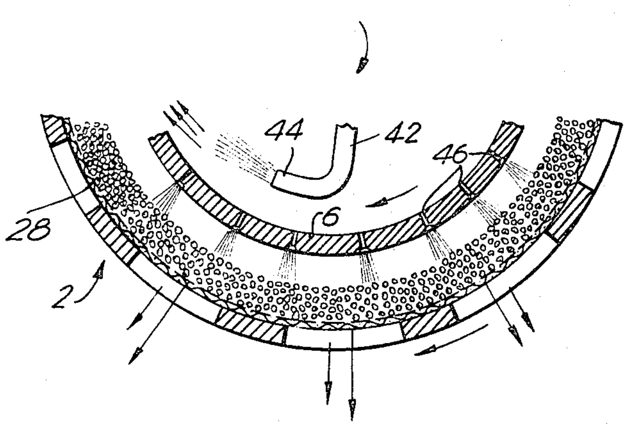


FIG. 5



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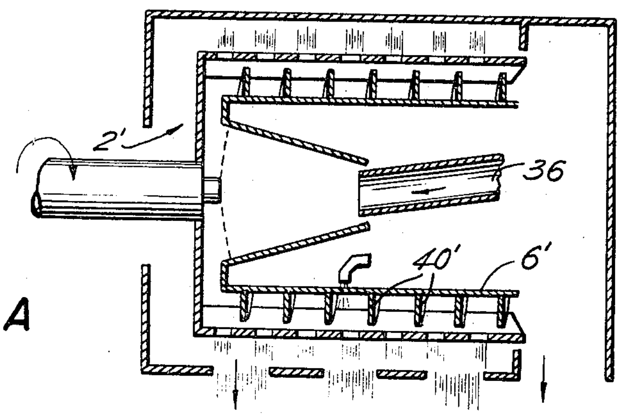

FIG. 6A
PRIOR ART

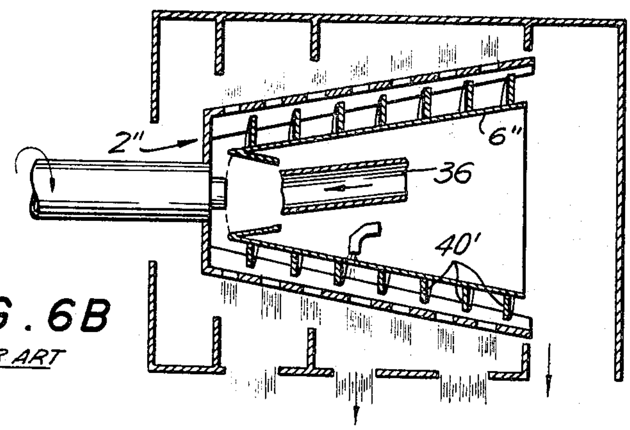

FIG. 6B
PRIOR ART

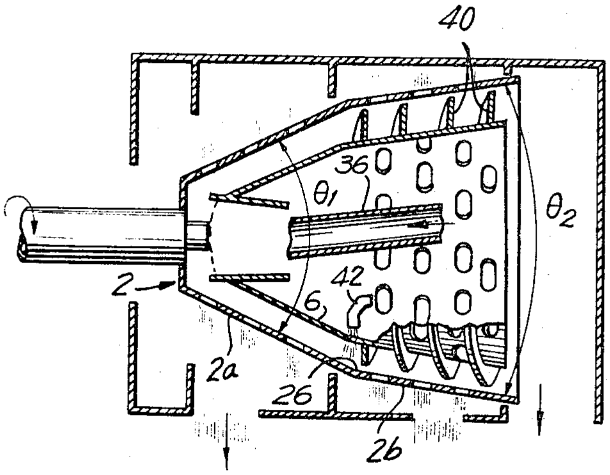

FIG. 6C

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United States Patent Office

3,419,148
Patented Dec. 31, 1968

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3,419,148

CONTINUOUS-TYPE CENTRIFUGAL MACHINE

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Filed Oct. 23, 1967, Ser. No. 677,321
Claims priority, application Japan, Oct. 22, 1966, 69,891/66
8 Claims. (Cl. 210—213)

ABSTRACT OF THE DISCLOSURE

Continuous separation of a slurry into liquid and solid phases is accomplished by providing the basket or bowl of the inventive centrifugal machine with two adjoining frustoconical screen elements, the apex angle of the element closer to the feed end of the screw being larger than that of the other screen element, a continuous blade being provided so as to vary the thickness of a layer of the solid phase at the demarcation line between the screen elements, preferably only in the area of the screen element closer to the discharge end.

In the sugar manufacturing industry, the centrifugal machines used in the step of separating the sugar produced from its mother liquor are, almost without exception, those of the batch type.

In the sugar refining industry, similarly, centrifugal machines of the batch type are used in the affination process as well as the refined-product sugar process. Unlike in modern chemical industries where continuous centrifugal machines are rapidly replacing batch-type centrifugals because of the disadvantages of the latter, i.e. the attrition of power and time needed for acceleration or deceleration, uneven power consumption, additional manpower and supplies required, etc., centrifugals of the batch type are still exclusively used in the sugar industry for the following reasons.

A continuous centrifugal machine of conventional design cannot produce a sufficiently high centrifugal force to effect complete separation of the solid sugar crystals from the highly viscous mother liquor, nor is it possible to provide for a sufficient retention time during which such crystals may be washed and dehydrated.

On the other hand, in the case of low-quality sugar, separation of fine crystals from the highly viscous mother liquor has been continuously effected by means of a centrifugal machine of the conical automatic-discharge basket type. In this instance, a sufficiently high filtration efficiency may be attained because of the centrifugal force obtainable and the extremely thin crystal layer that is formed within the basket.

However, since it is impossible to provide for a sufficient retention time for the crystals, no sufficient washing and dehydration effect can be expected.

A primary object of the present invention is to provide a continuous centrifugal machine which is so constructed that in the initial stage of filtration and separation both automatic delivery of the crystals and maintenance of a thin cake layer are achieved, and in the subsequent stage there is controlled retention of the crystals and, at the same time, there occurs an efficient washing of said crystals.

According to one of the main features of the invention, the centrifugal machine comprises, in combination, a basket or bowl as well as a screw adapted to discharge the solid phase of the slurry that is centrifuged; the bowl including two frustoconical screen elements having different apex angles, the angle of the element closer to the feed end being larger than that of the other screen element; and there being also provided a conveying blade for the screw, only in the area adjacent the screen element closer to the discharge end, thereby varying the thickness of a crystal layer at the demarcation line between the two screen elements.

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According to other important features, slurry distribution means are provided inside the screw conveyer, including a dispersing cone and a dispersing element, for accelerating the slurry, evenly dispersing the same over the screen elements of the basket or bowl.

Yet another inventive feature of the invention relates to the provision of at least one supply pipe for a washing solution, in the region of the demarcation line between the screen elements, whereby the solution is discharged in jets against the solid-phase layer at the demarcation line.

Still another inventive feature relates to the provision of a bank or wall member inside the screw for centrifugally accelerating the washing solution before it is discharged from said supply pipes against the solid-phase layer.

It is also contemplated, according to the invention, to provide means for recovering the spent washing solution independently from the liquid phase centrifugally separated from the slurry.

The various objects, features and attendant advantages of the present invention will become more apparent from the following description of a preferred, exemplary embodiment, when considered in conjunction with the accompanying drawings wherein

FIG. 1 is a side-elevational view, partly in section, of a horizontal centrifugal machine embodying the principles of this invention;

FIG. 2 is a sectional detail view of the centrifugal screen elements illustrated in FIG. 1;

FIG. 3 is a view similar to that of FIG. 2, showing a different arrangement of screen elements that may be used in a modified embodiment of the invention;

FIG. 4 is a longitudinal sectional view showing a typical washing device used in the apex zone of the basket or bowl illustrated in FIG. 1;

FIG. 5 is a scross-sectional view taken along line V—V in FIG. 4;

FIGS. 6A and 6B show, in section, schematic details of conventional centrifugal machines, for comparison purposes; and

FIG. 6C shows, in a sectional view similar to those of FIGS. 1, 6A and 6B, the centrifugal machine embodying the principles of the invention.

The invention will hereinafter be described in full detail. Referring to FIGS. 1 to 5 and 6C of the drawings, a basket or bowl **2** is rigidly secured to one end of a hollow main shaft **4**. A screw or conveyor **6** is rigidly secured to one end of a shaft **8** passing through said main shaft **4**.

The bowl **2** and screw **6** are driven by a V-pulley **10** from a conventional motor **12** in the same rotational direction. The respective shafts **4** and **8** are driven at slightly different velocities of rotation by means of a differential drive mechanism built into the V-pulley **10**.

This mechanism is not described or illustrated herein in detail since it does not form the subject matter of this invention. A co-opending, co-assigned patent application entitled "Centrifugal Machine with Differential Drive," Ser. No. 677,320, filed Oct. 23, 1967, discloses a modified version of the mechanism in full detail. Some of the structural elements of the present application are correlated hereunder, for the sake of better understanding, with the corresponding elements of the co-pending application, as follows: the bowl and the screw of this application, with their respective shafts, identified by numerals

2, 6, 4 and 8, correspond to elements 14, 6, 12 and 54, respectively, of the other application; the V-pulley 10 and the motor 12 have their counterparts in the drive cylinder 22 and the motor 18 of the other case; the slurry inlets are 36 in this case and 4 in the other, while the liquid outlets are numbered 60*a* and 8, and the solid outlets 54 and 10, respectively, in the two applications.

One end of the differential drive mechanism is connected to a shaft through chain wheels 16 and 18, as well as a chain 20, and the chain wheel 18 on the shaft is provided with a friction plate 22 which serves as a torque limiter under overload conditions. A conventional reversible motor 24 is provided for the differential system of this particular centrifugal machine. Plate 22 is an overload relief device for the chain wheel 18.

It should be noted that there is a major difference between the mechanisms of the two applications. In the present case, the just described elements 16 to 24, in operative connection with the V-pulley 10, serve to increase or to reduce the difference between the respective velocities of the shafts 4 and 8, and the motor 24 serves just this purpose. In the other application, however, a system of interconnected arms and a braking mechanism are provided, identified by numerals 40 to 50, for compensating temporary overloads between the two shafts, and for keeping an element of the differential drive mechanism in a predetermined (preferably vertical) position. The mechanism of the presently disclosed centrifugal machine will be described in more detail as the description proceeds.

When the rotational velocity of the main shaft 4, that is to say, of the bowl 2, is held constant and the difference with respect to the velocity of rotation of the screw shaft 8 is to be varied, it is sufficient to drive the shaft at the given velocity of rotation. This mechanism, although related to that of the other application and known in its basic principles, does not form part of the inventive features of the continuous-type centrifugal machine.

The velocity of rotation of the chain-wheel shaft is variable, and it is thus possible, even in the course of operation, to select the desired difference between the rotational velocities of the shafts 4 and 8.

The bowl 2 consists of two frustoconical portions, one identified by numeral 2*a*, having a wide apex angle, and the other, denoted 2*b*, having a narrow apex angle, the demarcation line between the portions being indicated at 26 (FIGS. 4 and 6C). Thus the bowl actually consists of two conical portions 2*a* and 2*b*, connected in series as a single unit.

Inside the bowl 2 is built a filter wire-mesh screen 28. This screen may be replaced by the combination of a sheet screen 28*a* and a backing screen 28*b*, as shown in FIG. 3.

In FIG. 2, numeral 30 denotes a retaining bolt adapted to prevent dislocation of the wire-mesh screen 28 in the direction of rotation. Within the bowl 2 and at the end thereof, there is a dispersing element 32 (see FIG. 1), adapted to uniformly disperse the load over the screen 28, the element 32 being rigidly secured to the main shaft 4.

The screw 6 is located within the bowl 2 and has a dispersing cone 34 on the inner side thereof and concentrically therewith. The dispersing cone serves to accelerate a solution of slurry supplied through a feed-in pipe or conduit 36 which is partially inserted into the cone 34 through a narrow annular clearance and, then, it feeds the slurry to the dispersing element 32 through a passageway 38 formed in the screw 6. The latter has conveying blades 40 in the outer conical zone 2*b* only which, as aforesaid, has a relatively small apex angle.

Indicated by reference numeral 42 is a crystal washing-solution supply pipe located within the screw 6, and the washing solution, supplied through its nozzle 44 under uniform pressure, is sprayed over the filter screen 28 through channels 46 formed in the screw 6.

The above-mentioned supply pipe 42 and the channels 46 are located along the demarcation line 26, between the two frustoconical cone portions 2*a* and 2*b* of the bowl 2. A liquid receiver 48 is located on the peripheral surface of the bowl 2 and it carries a partitioning plate 50 in a plane comprising the demarcation line 26, between the truncated cones 2*a*, 2*b*, whereby the liquid receiver 48 is divided into two liquid compartments, namely 48*a* and 48*b*.

A chute 52 is made up of a metal plate lined with rubber or other elastic material, and serves to receive, while decelerating, the crystals extruded by the screw 6 from the centrifugal field within the bowl 2, and to guide said crystals to an outlet 54 formed in the bottom of a crystal chamber 56.

Especially when it is desired that the breakage of the crystals be reduced to a minimum, an improved shock-absorbing effect may be attained if a flexible tube 58 filled with compressed air is disposed behind the chute 52.

In operation, the slurry to be centrifuged is fed through the pipe 36. The slurry is gradually accelerated by the dispersing cone 34, whence it is forced into the dispersing element 32 through passageway 38. The slurry is now further accelerated by the dispering element 32 and at the same time, is radially dispersed thereby unto the filter screen 28. Then, the slurry keeps sliding on the inner truncated cone 2*a* of the screen 28, which is steeply inclined, toward the demarcation line 26, forming a thin layer.

In the process, the liquid phase of the slurry is centrifugally discharged out of the bowl 2 through the openings in the screen 28. The liquid phase is further guided into the liquid chamber 48*a* from where it is finally discharged out of the centrifuge through an outlet 60*a*. Outlet 60*b* will be described somewhat later. Thus, the solid crystals remaining on the filter screen 28 are forced toward the demarcation line 26, forming a thin layer of substantially uniform thickness.

For this reason, filtration resistance is not great, with the liquid phase of the slurry being substantially completely withdrawn from the bowl, as it passes the part of the filter screen 28 corresponding to the inner conical zone 2*a* of the bowl 2.

On the other hand, after passing the demarcation line 26, the crystals cannot move by themselves, but are transported under mild thrust by the conveying blade 40 of the screw 6 up to the end of the bowl 2.

It will be apparent that if the relative velocities between the rotational speeds of the bowl 2 and the screw 6, and the pitch of the conveying blade 40, are previously properly set, the crystals are successively delivered by the blade 40 from the demarcation line 26, thus forming a layer of uniform thickness, and at a controlled velocity, until they reach the end of the bowl 2. Thus, the time during which the crystals remain in the bowl may be completely controlled, assuming that the feeding rate of the slurry is constant.

While the crystals are continuously delivered in the above-described manner, if a washing solution is supplied near the demarcation line 26 from the supply pipe 42 inside the screw 6, the solution is forced through the channels 46 unto the crystals accumulated on the screen 28, whereby the crystals are purified.

After washing the crystals, the washing solution flows through the screen 28 into the liquid chamber 48*b*, to be ultimately recovered through the aforementioned exit or outlet 60*b*, separately from the liquid phase, which has a different composition, and is discharged through the outlet 60*a*, as explained before.

Since the washing is effected where the crystal layer shifts from a relatively thin area to a thicker area, the washing solution is brought into more effective contact with the surface of the individual crystals as compared with the conventional discharge of a washing solution unto the surface of a thick layer of crystals. Stated differently, a more thorough washing effect can be had with a lesser amount of washing solution.

In essence, the present invention provides a continuous centrifugal machine which effects filtration of the slurry in an initial thin layer within the bowl **2**, washing the residual crystals along the line of demarcation **26** between the thin layer and a thick layer that follows, and finally, dehydrating the crystals in a retention time controlled by the conveying blade **40**, whereby a considerably more efficient liquid-solid separation is attained than has been possible with conventional centrifugal machines of the continuous type.

The fundamental principles of this invention will now be compared with the principles involved in conventional centrifugal machines, reference being had to FIGS. 6A and 6B for the latter. FIG. 6C shows the principles underlying the operation of the continuous-type centrifugal machine according to the present invention.

FIG. 6A shows a machine, somewhat schematically, having a cylindrical basket **2'** and FIG. 6B shows one having a conical basket **2''**, the latter with a single inclined surface. In both prior-art machines there is respectively provided a conveying blade **40'** throughout the entire axial length of the baskets. Assuming that the baskets of these three machines have the same length and maximum diameter, the machine of FIG. 6A obviously has the maximum filtration area. However, since the basket **2'** of FIG. 6A is cylindrical, the crystals cannot travel, with the result that the conveyance of the crystals must be commenced as soon as the slurry is fed into the machine. Thus, the conveying blade **40'** agitates the slurry which has been only partially filtered, resulting in a reduced filtration capacity.

Moreover, since the solid phase is held in contact with the blade for a relatively long time, there is an increased tendency for the crystals to be crushed. Of particular importance is the fact that more power is required to drive the screw **6'**. In addition, the crystal layer will be uniform over the entire length of the basket **2'** so that no effective washing can be expected.

The machine of FIG. 6B has a somewhat smaller filtration area, and while the power required to drive the screw **6''** is smaller by the amount corresponding to the angle of taper of the basket or bowl, it has, otherwise, the same disadvantages as the structure of FIG. 6A. Rather, this machine is more disadvantageous in that the thickness of the layer is large in the initial stage of filtration.

If the velocity of the screw **6''** is increased in order to overcome this disadvantage, the thickness of the layer will be decreased, but as an increased amount of the solids comes in contact with the blade **40'**, the crystals are more liable to be broken.

In the case of the inventive machine, shown in FIG. 6C, the filtration area falls somewhere between the areas of the prior-art machines of FIGS. 6A and 6B. Furthermore, in the inner conical zone **2***a* of the bowl **2**, which has a relatively great angle of taper, no power is required at all to advance the crystals.

The screw **6** has no blade in the abovementioned inner conical zone **2***a* and, accordingly, the filtration area is not sacrificed by the presence of such a blade. Moreover, the inner frustoconical portion **2***a* is so steeply flared that the slurry travels fast, yielding an extremely thin crystal layer. Actually, therefore, the filtration speed of the inventive machine is the highest, with the additional advantage of stabilized rotation.

The apex angle θ_1 as shown in FIG. 6C, of the inner frustoconical cone **2***a* of the bowl **2** is an important factor in the determination of the thickness of said crystal layer, and the theoretically optimum apex angle is about twice the angle of static friction between the crystal grain and the surface of the screen **28**. Thus, the apex angle preferably ranges between 100° and 50°.

At the demarcation line **26** of the bowl **2**, the crystal layer changes in thickness so that the washing of the crystals may be carried out more effectively. Furthermore, since the distance over which the crystals are forced out by the conveying blade **40** is smaller than the corresponding distances for the other two, conventional machines shown in FIGS. 6A and 6B, power consumption is drastically reduced.

In addition, as the above-mentioned distance, i.e. the outer truncated cone **2***b* of the bowl **2** is mildly tapered (apex angle $\theta_2=40°$ or less), the crystals are slightly loosened as they travel, without being compacted, into a tight layer, with the result that the dehydration of the crystals is also greatly enhanced.

Thus, when the three centrifugal machines as shown in FIGS. 6A, 6B and 6C, having bowls of the same maximum diameter and the same length, are supplied with the same amount of the same slurry, the machine of FIG. 6C, according to this invention, needs only one-half to one-third as much washing solution as is required by the other two, conventional machines, and a substantially reduced amount of power is needed for the transfer of the crystals.

Thus, the centrifugal machine of this invention is superior to the conventional continuous machines, economically speaking. Still more satisfactory results will be attained if the washing device is constructed as shown in FIGS. 4 and 5. The nozzle **44** of the washing-solution supply pipe **42** discharges in the direction of rotation of the bowl **2** and screw **6** so as to avoid a collision of the washing solution with the screw, and a ring-shaped bank or wall portion **62** (FIG. 4) is disposed so that after a sufficient pressure is built up by the centrifugal force, the solution is caused to jet against the crystal layer on the screen **28**.

When the liquid channel **46** is located axially within one pitch from the origin of the conveying blade **40**, the thickness of the crystal layer will change from zero to maximum. Thus, the jets of the washing solution are fully brought into contact with the surface of almost all the crystals so that an efficient washing result can be obtained.

More than one washing-solution supply pipe **42** may be installed in preferred positions within the bowl, and one of the pipes may be used for the purpose of promoting the drying of the cake, by the aid of superheated steam.

The foregoing disclosure relates only to a preferred, exemplary embodiment of the invention, which is intended to include all changes and modifications, as well as additions to the example described, which are within the scope and spirit of the invention as set forth in the objects and features outlined in the preamble, and the appended claims.

Thus, it will be appreciated, the inventive features disclosed in this application may be embodied in a continuous-type centrifugal machine used in various industries for separation purposes as well although it has been mentioned herein, as a matter of illustration, for purposes of the sugar manufacturing and refining industries.

What we claim is:

1. A continuous-type centrifugal machine comprising, in combination, bowl means capable of rotating at a velocity sufficiently high to separate a slurry into liquid and solid phases; screw means capable of rotating at a velocity different from that of said bowl means, and having respective feed and discharge ends; said bowl means and said screw means having respective drive shafts; and a mechanism for separately driving said bowl means and said screw means at predetermined different velocities, said drive shafts being substantially coaxially supported in conjunction with said mechanism; said bowl means including two adjoining substantially frustoconical screen elements, the apex angle of one screen element which is located near said feed end of the screw means being larger than that of the other screen element which is located near said discharge end of the screw means; and further comprising a sole conveying blade associated with said screw means and being restricted to the area adjacent said other screen elements, thereby varying the thickness of a layer of the solid phase by said screw means at the demarcation line between said screen elements.

2. The centrifugal machine as defined in claim 1, wherein said feed end of the screw means is associated with feed-in means for the slurry while said discharge end of the screw means is associated with discharge means for at least one of the liquid and solid phases.

3. The centrifugal machine as defined in claim 1, further comprising slurry distribution means inside said screw means and including a dispersing cone for centrifugally accelerating the slurry, and a dispersing element for further accelerating and dispersing the slurry evenly over said screen elements.

4. The centrifugal machine as defined in claim 3, wherein the apex angle of said one screen element ranges between 100° and 50° while that of said other screen element is not more than 40°, and wherein said dispersing cone is in the area adjacent said one screen element.

5. The centrifugal machine as defined in claim 1, further comprising at least one supply pipe for a washing solution, disposed adjacent the demarcation line, whereby the solution introduced by way of said supply pipe is discharged in jets against the layer of the solid phase at the demarcation line.

6. The centrifugal machine as defined in claim 5, further comprising means for recovering the washing solution independently from the discharged liquid phase.

7. The centrifugal machine as defined in claim 5, further comprising annular bank means associated with said screw means for centrifugally accelerating the washing solution before being discharged from said supply pipe.

8. The centrifugal machine as defined in claim 7, wherein said bank means extends inwardly from said screw means, providing a trough in which the washing solution is held by centrifugal force, during operation, against a portion of said screw means substantially parallel with said one screen element, said screw-means portion having therein radial channels for spraying the solution against the layer of the solid phase.

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U.S. Cl. X.R.

210—215, 374, 380