(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 447 742 A2**

(12) **EUROPEAN PATENT APPLICATION**

(21) Application number: **91100071.9**

(51) Int. Cl.[5]: **B04B 1/20**

(22) Date of filing: **02.01.91**

(30) Priority: **19.03.90 JP 69019/90**

(43) Date of publication of application:
25.09.91 Bulletin 91/39

(84) Designated Contracting States:
AT BE CH DE DK ES FR GB GR IT LI LU NL SE

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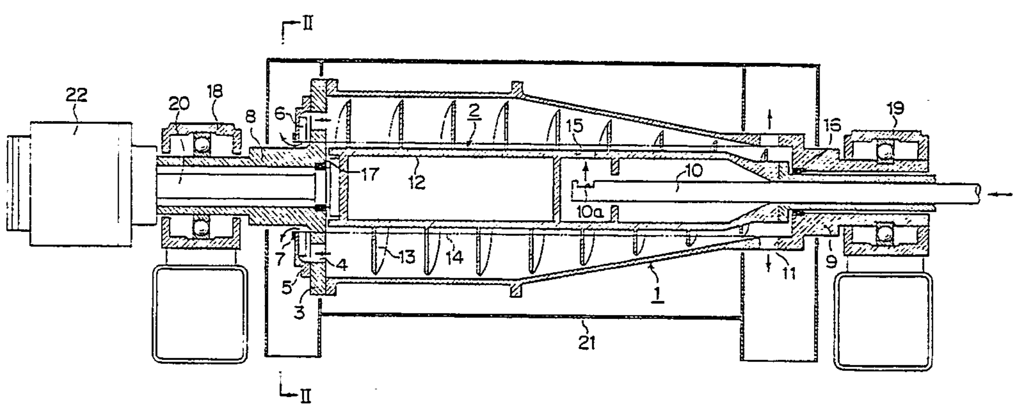
(54) **Decanter centrifuge.**

(57) A decanter centrifuge used for solid-liquid separation of a feed solution containing suspended solids. According to a preferred embodiment, plural number of clarified liquid discharge ports are formed on a bowl-head of a rotating bowl. On the other hand, a ring-shaped weir is mounted on the bowl-head, coaxially has a ring-shaped overflow cavity communicating with each liquid discharge port and is provided with a peripheral opening directing the rotative axis of the bowl-head. Additionally, plural number of reducing blades are provided in the ring-shaped overflow cavity in a radial form from the rotative axis of the bowl-head. Then, the cavity is divided into plural number of portions while each reducing blade is fixed to the inner face of the ring-shaped weir. Due to the reducing blades, appropriate quantity of the clarified liquid is overflown.

FIG. 1



Background of the Invention

1. Field of the Invention

This invention relates to a decanter centrifuge used for a solid-liquid separation of a feed solution containing suspended solids.

2. Prior Art

As shown in Fig. 1, this type of centrifuge comprises a bowl 1 which rotates with a high rotative speed, a screw-conveyor 2 which is disposed coaxially with the rotating bowl 1 and which is pivoted by the rotating bowl 1 so as to be included in the bowl 1. Then, a screw blade 13 is helically provided around the conveyor 2 so that there is a narrow gap between the inner surface of the bowl 1 and the external circumference of the screw blade 13. The rotating bowl 1 and the screw conveyer 2 rotate in the same direction, while there is a necessary differential rotative speed between the bowl 1 and the conveyor 2.

A feed solution is introduced, through a supply pipe 10, to the rotating bowl 1 from the supply port 10a of the supply pipe 10. Then, due to centrifugal force caused by the rotation of the bowl 1, the feed solution is sprayed to the inner surface of the rotating bowl 1. Therefore, a pool 14 is formed in the bowl 1. Thus, the solidified particles of the suspended solids are separated from a clarified liquid to be sedimented on the bottom of the pool 14. The solidified particles of the suspended solids are scraped together towards the right side of this figure by the screw blade 13 and discharged. On the other hand, the clarified liquid overflows from a liquid discharge port 4 formed on a bowl-head 3 of the bowl 1 and is discharged from the bowl 1.

In prior art, as shown in Fig. 3, a ring-shaped or a board-shaped weir 30 is normally attached to the external side of the base of the bowl-head 3 adjacent to the liquid discharge port 4, in order to adjust the level of the pool 14.

Generally, the accelerating power is given by the following equation (1).

$$hp = 7.61 \times Q \times (2r)^2 \times N^2 \times 10^{-7} \quad ......(1)$$

where hp : accelerating power (KW), Q : flow rate (m^3/hr), r : radius (m), N : number of revolution (rpm)

As shown in equation (1), as the radius (r) is decreased, that is to say, as the level of the pool 14 is raised, the accelerating power (P) can be decreased resulting in saving the amount of required power. Additionally, depending on the type of structure of the screw conveyor or solid-liquid separating efficiency, when the level of the pool 14 is raised, the capacity of the rotating bowl 1 for containing the feed solution can be increased. This provides an improved separating efficiency.

In view of raising the level of the pool 14, as shown in Fig. 4, a liquid discharge port 4 is formed so as to cross slantingly the base of a bowl-head 3.

Besides, there are some conventional apparatus, each of which is characterized by each discharging method of the clarified liquid. For example, in Japanese Utility Model Publication No. 60-31793 using a skimming method, a pipe-shaped skimming-blade is immersed in the clarified liquid. Then, utilizing the rotational energy of the clarified liquid, this liquid is introduced along the skimming-blade to be discharged. Further, another apparatus is shown in Japanese Patent Publication No. 63-31261. Although the object of this conventional apparatus is different from the object of the present invention, a method for raising the level of a discharged liquid is shown. In this conventional apparatus, around the peripheral face of the screw conveyor, paths for discharging solids and paths for discharging clarified liquid are provided. They radiate from the axis of this screw conveyor. Side paths are also provided so as to communicate with the paths for discharging clarified liquid. Then, controllers for the quantity of the discharged clarified liquids are equipped on the side paths, thereby, the quantity of the discharged liquids can be adjusted. This provides apparatus by which the level of the discharged liquid can be raised.

In order to raise the level of the pool, generally the liquid discharge port provided on the bowl-head should be formed so as to be adjacent to the axis of the bowl head. However, torsional stress is increased at this axis, further, bending stress in the direction of the axis is applied there. Accordingly, the liquid discharge port placed to be adjacent to the rotating axis often causes a problem related to the structural strength of the bowl-head. Therefore, this method for raising the level of the pool always can not be carried out because of the problem related to the structural strength.

Further, in the method explained referring to Fig. 4, since the liquid discharge port 4 is formed so as to cross slantingly the base of the bowl-head 3. the level of the pool can be raised to some degree comparing apparatus explained referring to Fig. 3. However, also in this method, there remains the problem related to the structural strength.

On the other hand, apparatus shown in Japanese Utility Model Publication No. 60-31793 requires high energy for discharging, thus, can not save the amount of required power. Next, apparatus shown in Japanese Patent Publication No. 63-31261 is not suitable for discharging solids having a low water content, additionally, this apparatus has problems related to the abrasion of the skimming-blade and other problems related to its complicated structure.

Summary of the Invention

It is therefore the main object of the present invention to provide a centrifuge, whose pool level can be raised without the problem of structural strength, thereby by which the amount of required power can be saved and high efficiency for separating can be attained.

In a decanter centrifuge related to the present invention, a rotating bowl is provided with at least one solid discharge port and at least one clarified liquid discharge port. A screw conveyor is disposed coaxially with the rotating bowl so as to be included in the rotating bowl. The rotating bowl and the screw conveyor are rotated in the same direction with a differential rotative speed. A feed solution to be separated is introduced into a ring-shaped space formed between the rotating bowl and the screw conveyor. The feed solution is continuously separated to be solid and liquid by means of a centrifugal force. Then, the solid is discharged from the solid discharge port and the liquid is discharged from the clarified liquid discharge port. This centrifuge is characterized by the provision of clarified liquid discharging apparatus which comprises the clarified liquid discharge port, a ring-shaped weir and plural number of reducing blades.

Each clarified liquid discharge port is formed on a bowl-head of the rotating bowl so that the inner side of the bowl and the external side of the bowl-head can communicate with each other.

The ring-shaped weir is mounted on the external face of the bowl-head. Then, a ring-shaped overflow cavity is provided in the ring-shaped weir so as to communicate with each clarified liquid discharge port. The ring-shaped weir coaxially has a peripheral opening directing the rotative axis of the bowl-head.

The plural number of reducing blades are provided in the ring-shaped overflow cavity of the ring-shaped weir in a radial form from the rotative axis of the bowl-head. Then, the cavity is divided into plural number of portions while each reducing blade is fixed on at least one of the internal face of the ring-shaped weir and the external face of the bowl-head.

The operation of the present invention is explained referring to Fig. 1.

At least one liquid discharge port 4 is provided on the periphery of the bowl-head 3, or preferably plural number of liquid discharge ports 4, 4 are provided so as to be disposed on the periphery of the bowl-head 3 with a predetermined space so that the inner side of the rotating bowl 1 and the external side of the bowl-head 3 can communicate each other through the liquid discharge port 4. Then, a ring-shaped weir 5 is mounted on the external face of the base of the bowl-head 3. In the weir 5, there is a ring-shaped overflow cavity, which commnunicate with each liquid discharge port 4 and which coaxially has a peripheral opening directing the rotative axis of this bowl-head 3.

Therefore, since the level of the pool 14 is determined by the position of the overflow cavity of the weir 5 on its radius direction, the level of the pool 14 can be raised easily. However, even if the level is raised, since the clarified liquid beyond the liquid discharge port 4 reaches soon at the overflow cavity of the above mentioned ring-shaped weir 5, blade free vortex flow is produced. Then, the clarified liquid overflows the ring-shaped weir 5 with a peripheral velocity, which is the same as or larger than its peripheral velocity at the liquid discharge port 4. Accordingly, pressure drop is increased at the overflow cavity of the ring-shaped weir 5 resulting in decreasing of the amount of overflown clarified liquid. In the present invention, in order to prevent this situation, that is to say, in order to prevent the blade free vortex flow, plural number of blades 6 as speed reducing blades are provided in the lip portion of the ring-shaped weir 5 in a radial form. Each speed reducing blade can be fixed to the internal face of the ring-shaped weir 5, to the external face of the bowl-head 3, or to the both faces so as to cross them. Due to the speed reducing blades 6, the relation between the peripheral velocity (v) and the radius (r) is shown by the equation; $v = r\omega$, where (ω) is rate of rotation. That is to say, when the rate of rotation (ω) is fixed, since the peripheral velocity is proportional to the radius, this velocity can be reduced by reducing the radius. Therefore, the pressure drop is not produced relatively. As a result, appropriate quantity of overflow can be attained.

On the other hand, theoretically, depending on the provision of the speed reducing blades 6, the produced pressure drop is changed, so that the amount of required power can be decreased as explained after.

In this section, the peripheral velocity and the radius at the clarified liquid discharge port 4 are indicated by V_4 and r_4 respectively and the peripheral velocity and the radius at the ring-shaped weir 5 are indicated by V_7 and r_7 respectively.

in case of the blade free vortex flow...

$V_4 r_4 = V_7 r_7$, therefore,

$$V_7 = V_4 \frac{r_4}{r_7}$$

in case of the provision of the reducing blades...

$V_4 = r_4\omega$, $V_7 = r_7\omega$, therefore,

$$V_7 = V_4 \frac{r_7}{r_4}$$

Further, as for the pressure drop,

$$\Delta P = \int \frac{1}{g}\frac{V^2}{r}dr$$

therefore, in case of the blade free vortex flow...

$$\Delta P_A = \int_{r_7}^{r_4} \frac{1}{g}\frac{V^2}{r}dr$$

$$= -\frac{1}{2g}V_4^2\left(1 - \frac{r_4^2}{r_7^2}\right)$$

in case of the provision of the reducing blades...

$$\Delta P_B = \int_{r_7}^{r_4} \frac{1}{g}\frac{V^2}{r}dr$$

$$= \frac{1}{2g}V_4^2\left(1 - \frac{r_7^2}{r_4^2}\right)$$

Accordingly, $\Delta P_A > \Delta P_B$. That is to say, in case of the blade free vortex, the pressure drop is increased, and the amount of overflown liquid is decreased.

On the other hand, as for the amount of required power,

$$hp = \int T\omega dV$$

$v = r\omega$ and

$T = Q\frac{Vr}{g}$
therefore,

$$hp = \frac{Q}{g}\int_{V_7}^{V_4?} V^2 dV$$

Then, in case of the provision of the reducing blades, if the same amount of overflown liquid is discharged, the decreased amount of required power Δhp (KW) is shown by the following equation;

$$\Delta hp = \frac{Q}{g}\left(\frac{V_4^3}{3} - \frac{V_7^3}{3}\right)$$

As a result, in case of the provision of the reducing blades, $V_4 > V_7$, therefore, the amount of required power is decreased. On the other hand, in case of the blade free vortex flow without the reducing blades, $V_7 > V_4$, therefore, the amount of required power is increased.

Further objects and advantages of the present invention will be apparent from the following description, reference being had to the accompanying drawing wherein preferred embodiments of the present invention are clearly shown.

Brief Description of the Drawings

Fig. 1 illustrates a decanter centrifuge related to the present invention;

Fig. 2 is a cross sectional view taken on line II-II of Fig. 1;

Figs. 3 and 4 illustrate conventional apparatus for discharging clarified liquids.

Description of the Preferred Embodiment

Now, the present invention is described more particularly.

As shown in Fig. 1, a decanter centrifuge related to the present invention has a following structure.

A rotating bowl 1 is a combination of a conical shape and a cylindrical shape. A bowl-head 3 is fixed at the larger radius side of the rotating bowl 1 so as to enclose completely the rotating bowl 1. The hollow axis 8 of the bowl-head 3 is extended from the bowl-head 3 so as to communicate with the hollow of the rotating bowl 1. On the other hand, at the smaller radius side of the rotating bowl 1, the hollow axis 9 of the bowl 1 is extended from the back end of the bowl 1 so as to communicate with the hollow of the rotating bowl 1. The hollow axis 8 of the bowl-head 3 and the hollow axis 9 of the bowl 1 are pivoted by bearing stands 18 and 19 respectively. Accordingly, the rotating bowl 1 can be supported horizontally and rotated with a high rotative speed by a rotational force, which is transformed by rotating driving means (not shown).

In the hollow portion of the rotating bowl 1, a screw conveyor 2 is provided. The screw conveyor 2 is pivoted coaxially with the rotating horizontal axis of the bowl 1 by means of bearings 16 and 17. A hollow tube 12 of the screw conveyor 2 is provided horizontally at the center of the rotating bowl 1. A screw blade 13 extends helically the full length of the hollow tube 12 so as to almost reach the inner surface of the bowl 1. In the hollow axis 8 of the bowl-head 3, a transforming rod 20 is provided. Its one end is connected to the end face of the hollow tube 12 of the screw conveyor 2 and its another end is connected to a gear unit 22. The rotational force from the above mentioned rotating driving means (not shown) is transformed, through the intermediary of the gear unit 22, to the transforming rod 20. Thus, the screw conveyor 2 can be rotated with the high rotative speed. The rotating bowl 1 and the screw conveyor 2 are rotated in the same direction, while there is a slightly differential speed between them, which is accomplished by means of the gear unit 22.

A solid discharge port 11 is formed at the smaller radius side of the rotating bowl 1 on the right side of this figure so that solidified particles scraped together can be discharged from the solid discharge port 11. Then, liquid discharge ports 4, 4 are formed on the base of the bowl-head 3 at the larger radius side of the rotating bowl 1.

The portion, where the clarified liquid is overflown from each liquid discharge port 4, corresponds to clarified liquid discharging apparatus. Since the present invention is characterized by this portion, this portion will be explained closely referring to Fig. 2.

The above mentioned plural number of clarified liquid discharge ports 4, 4 are formed so as to be disposed on the periphery of the base of the bowl-head 3 with a predetermined space and so as to be apart from the rotative center of the bowl-head 3 with a predetermined radius. Then, the ring-shaped weir 5 is mounted oil the gear unit-side face of the base of the bowl-head 3. In the weir 5, there is a ring-shaped overflow cavity, which communicate with each liquid discharge port 4 and which coaxially has a peripheral opening directing the rotative axis of this bowl-head 3. Accordingly, as shown in Fig. 1, by connecting the overflow cavity and the liquid discharge ports 4, 4, a L-shaped cross section is formed. In the lip portion of this ring-shaped weir 5, plural number of reducing blades 6 are provided in a radial form so as to divide the ring-shaped overflow cavity into plural number of portions while each reducing blade is disposed between one liquid discharge ports 4 and an adjusting discharge port 4. Additionally, a ring-shaped adjusting weir board 7 is mounted on the gear unit-side face of the weir 5 so as to be removal. This adjusting weir board 7 can be changed another adjusting weir board 7 having a different inner diameter as desired, thus, the level of the pool 14 can be adjusted within the predetermined highest and lowest limits.

On the other hand, a supply pipe 10 is inserted through the hollow tube 12 of the screw conveyor 2 so as to supply the feed solution to be separated. Then, a hole 15 for the feed solution to be separated is formed on the peripheral face of the hollow tube 12 so as to correspond to the supply port 10a of the supply pipe 10. In the bowl 1, the external side of the hollow tube 12 can communicate with its internal side through the hole 15.

When the feed solution to be separated is supplied from the supply pipe 10, while the rotating bowl 1 and the screw conveyor 2 are rotated with each high rotative speed, the feed solution is introduced to the external side of the hollow tube 12 within the rotating bowl 1 through the hole 15 formed on the hollow tube 12. The feed solution in the rotating bowl 1 is continuously splashed toward the peripheral face of the rotating bowl 1 by a centrifugal force caused by the rotation of the rotating bowl 1. Therefore, the pool 14 is formed along the peripheral face of the rotating bowl 1. The solidified particles of the feed solution are separated from the clarified liquid to be segmented on the bottom of the pool 14. These particles are scraped towards the right side of Fig. 1 by means of the screw blade 13 and discharged from the solid discharge port 11. On the other hand, the separated clarified liquid is discharged from the liquid discharge ports 4, 4 formed on the bowl-head 3 and overflown beyond the adjusting weir board 7 outwardly from the rotating bowl 1.

A hood 21 is formed so as to encircle the rotating bowl 1. Therefore, the discharged solidified particles and the clarified liquid can be prevented from being splashed outside of the hood 21.

On the other hand, in this embodiment, the reducing blades 6 are fixed to only the internal face of the ring-shaped weir 5. However, they can be fixed to only the external face of the bowl-head 3 or to the both faces so as to cross the both faces.

Apparatus of the present invention can be utilized for concentrating separation of slurry as well as solid-liquid separation explained before. Hence, the meaning of the solidified particles in the present invention is not limited to the solids and includes also the concentrated solution.

The effect of the present invention is shown more clearly by examples.

Example 1

A decanter centrifuge was used in this example. In prior art, the pool level of this decanter centrifuge can not be designed to be higher than 130 mm due to the structural strength problem of the bowl-head 3 at its clarified liquid discharge port-side portion. This decanter centrifuge was deformed so as to be provided with clarified liquid discharging apparatus related to the present invention. Then, a slurry-solution, whose supplied slurry concentration is 0.5-1.0 %, was applied with the flow rate of 20 m^3/hr.

From this experiment, the level of the pool 14 could be raised to be 180 mm. It is concluded that the amount of required power could be saved with 15-25 %.

An additional experiment was performed. In this additional experiment, clarified liquid discharging apparatus, which has no reducing blade, was used.

In case of apparatus having reducing blades 6 on the ring-shaped weir 5, the concentration of the concentrated solution discharged from the solid discharge port was 4-5 %, which was a desired result. On the other hand, in case of apparatus having no reducing blade, a pressure drop was produced at an overflow cavity, thus, the quantity of overflown clarified liquid was decreased. Therefore, concentration of the concentrated solution discharged from the solid discharge port was 1.5-2.0 %, which was an extremely undesired result.

Example 2

For comparing the separating efficiencies between the conventional decanter centrifuge and the decanter centrifuge which was deformed so as to be provided with clarified liquid discharging apparatus related to the present invention. The pool level of the conventional centrifuge can not be designed to be higher than 130 mm. On the other hand, the decanter centrifuge related to the present invention has the pool level of 180 mm. Operations were carried out by these two kinds of centrifuges respectively, with the same concentration of the supplied slurry.

In case of the centrifuge whose pool level was 130 mm, the treating capacity for concentrating slurry (Q) was 20 m^3 / hr and the SS recovery was approximately 90 %. On the other hand, in case of the centrifuge whose pool level was 180 mm, the treating capacity for concentrating slurry (Q) was 25 m^3 / hr and the SS recovery was approximately 93-95 %. It is concluded that the containing capacity of the rotating bowl is increased, thus, the separating efficiency is extremely improved.

While preferred embodiments have been described, it is apparent that the present invention is not limited to the specific embodiments thereof.

Claims

1. A decanter centrifuge, in which a rotating bowl provided with at least one solid discharge port and at least one clarified liquid discharge port and a screw conveyor disposed coaxially with said rotating bowl so as to be included in said rotating bowl are rotated in the same direction with a differential rotative speed, with which a feed solution to be separated introduced into a ring-shaped space formed between said rotating bowl and said screw conveyor can be separated by means of a centrifugal force to be solid and liquid so that said solid is discharged from said solid discharge port and said liquid is discharged from said clarified liquid discharge port and which has clarified liquid discharging apparatus comprising:

   each clarified liquid discharge port which is formed on a bowl-head of said rotating bowl so that the inner side of said bowl and the external side of the bowl-head can communicate with each other;

   a ring-shaped weir, which is mounted on the external face of said bowl-head, in which a ring-shaped overflow cavity is provided so as to communicate with each clarified liquid discharge port and which coaxially has a peripheral opening directing the rotative axis of said bowl-head; and

   plural number of reducing blades which are provided in said ring-shaped overflow cavity of said ring-shaped weir in a radial form from the rotative axis of said bowl-head so as to divide said cavity into plural number of portions and so as to be fixed to at least one of the internal face of said ring-shaped weir and the external face of said bowl-head.

2. A decanter centrifuge according to claim 1, wherein plural number of clarified liquid discharge ports are provided so as to be disposed on the periphery of said bowl-head with a predetermined space and each reducing blade is provided between one clarified liquid discharge port and an adjusting clarified liquid discharge port.

3. A decanter centrifuge according to claim 1, wherein a ring-shaped adjusting weir board having a smaller inner diameter than the diameter of said peripheral opening is mounted on the external face of said ring-shaped weir so as to be removal.

FIG. 1

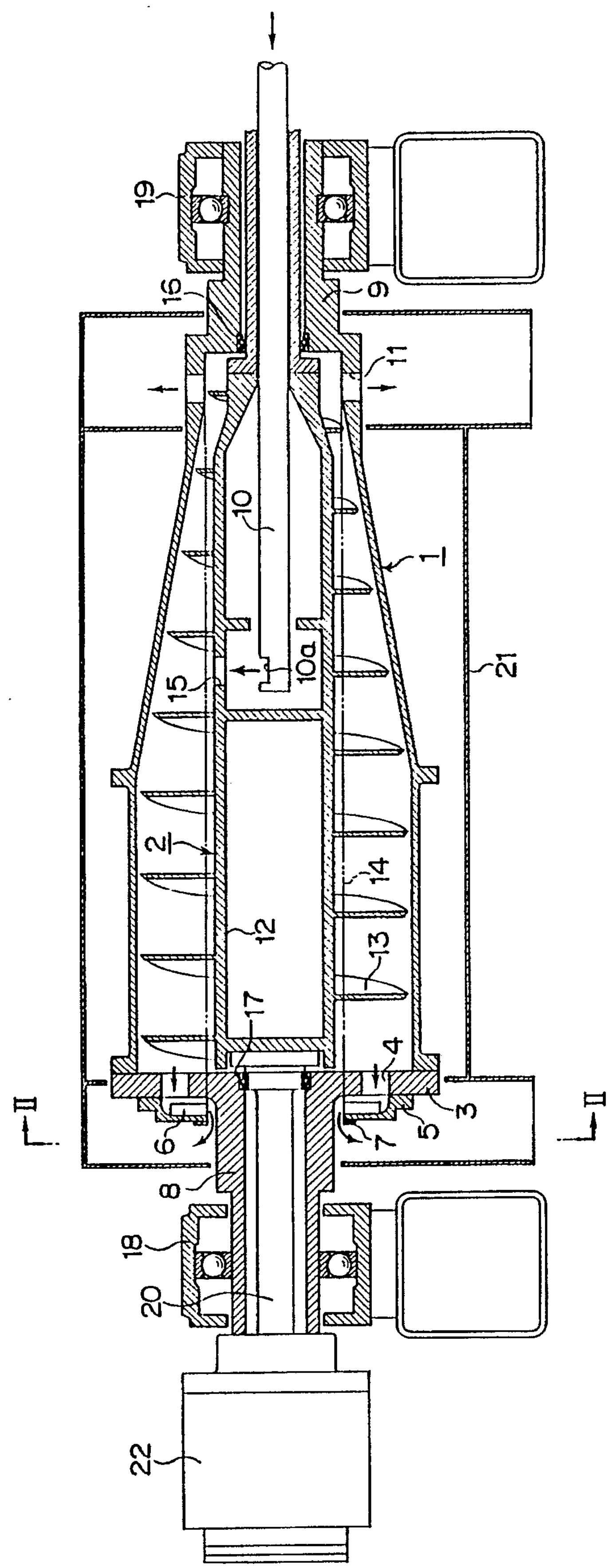


FIG. 2

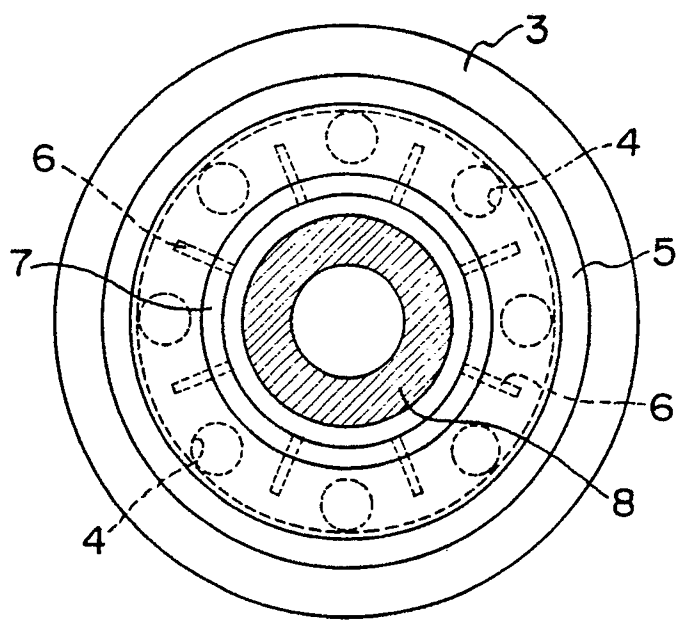


FIG. 3

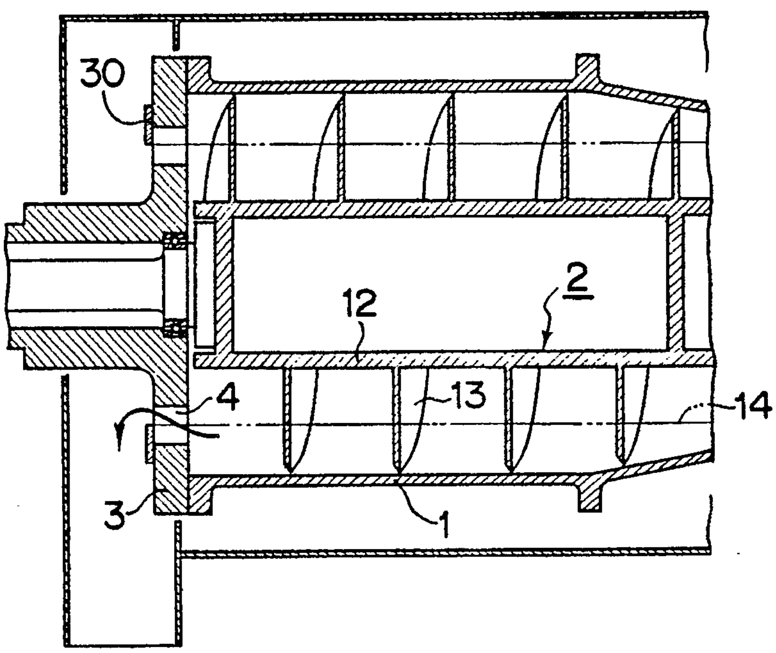


FIG. 4