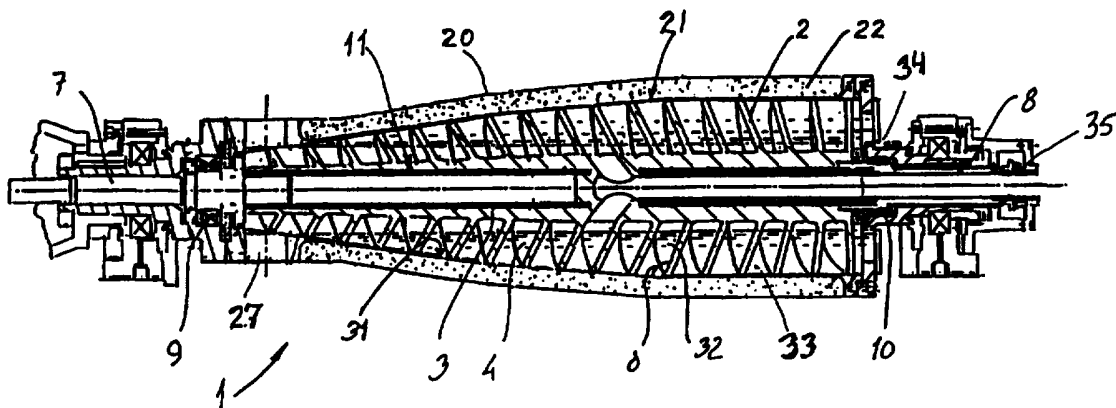




## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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<p>(21) International Application Number: PCT/DK95/00440 (22) International Filing Date: 6 November 1995 (06.11.95) (30) Priority Data: 1291/94 9 November 1994 (09.11.94) DK (71) Applicant (for all designated States except US): INCENTRA [DK/DK]; Langelandsvej 17, DK-5500 Middelfart (DK). (72) Inventor; and (75) Inventor/Applicant (for US only): MICHELSEN, Jan [DK/DK]; Røjlemosevej 75, Strib, DK-5500 Middelfart (DK). (74) Agent: HOLME PATENT A/S; Sankt Peders Stræde 41, DK-1453 Copenhagen K (DK).</p>		<p>(81) Designated States: AM, AT, AU, BB, BG, BR, BY, CA, CH, CN, CZ, DE, DK, EE, ES, FI, GB, GE, HU, JP, KE, KG, KP, KR, KZ, LK, LR, LT, LU, LV, MD, MG, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SI, SK, TJ, TT, UA, US, UZ, VN, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG), ARIPO patent (KE, LS, MW, SD, SZ, UG).</p> <p><b>Published</b> <i>With international search report. Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i></p>

(54) Title: DECANter CENTRIFUGE



## (57) Abstract

A decanter centrifuge (1) has a rotor comprising a helical conveyor (2) and a drum (20). The conveyor (2) comprises a conveyor hub (3) and helical flights (4), and the drum comprises an inner shell (21) of steel and an outer shell (22) of fibre reinforced plastic. The conveyor (2) consists of a shaft of tube form (11), primarily made from carbon fibre reinforced resin, and helical flights (4), primarily made from polyurethane. The flights (4) of the helical conveyor are formed in such a way that all the time they are in contact with the inner periphery of the drum (31). The division of the drum in an inner and an outer shell causes the mass of the drum to be reduced considerably.

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Decanter centrifuge  
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This invention relates to a decanter centrifuge for the  
5 separation of suspended solids from a liquid medium comprising  
a drum and a helical conveyor rotatable mounted therein.

Conventionally, a decanter centrifuge comprises a hollow drum  
of cylindrical/conical section rotatable supported by bearings  
10 and a helical conveyor therein, rotatable supported by  
bearings relative to the drum. Such a centrifuge is primarily  
used for the separation of solid particles from sludge, i. e.  
sludge from sewage treatment plants.

15 The centrifuge works by having the material to be cleaned from  
solids contents introduced to the internal of the drum through  
a pipe along the axis of rotation via an inlet arrangement. As  
the centrifuge rotates, the introduced sludge forms a toroidal  
shaped volume along the inner walls of the drum. By action of  
20 the centrifugal forces, the solid particles are concentrated  
as a layer along the inner wall of the drum, and from there  
they are transported by the helical conveyor towards one end  
of the centrifuge. As this will be the end formed as a  
frustro-cone having its narrow end at approximately the same  
25 diameter as the inner diameter as the toroidal-formed sludge  
volume, the solids leave the centrifuge having a comparatively  
higher concentration of solids than the incoming sludge. At  
the other end of the centrifuge, the cleaned liquid phase is  
leaving the centrifuge through holes or special extraction  
30 organs, such as a paring device.

A centrifuge has a limited peripheral speed, fixed by material  
properties and -stresses created by the rotation, and the  
internal toroidal volume is limited by the maximum length of  
35 the drum, which limit is primarily governed by the tendency of  
increased vibrations as the operational speed is getting close

to a critical frequency of vibration. Critical vibration frequencies are a property, mainly fixed by the stiffness to weight ratio of a body. The lowest ratio for the parts of a decanter centrifuge is found at the helical conveyor.

5

Known decanter centrifuges often have longitudinally mounted strips along the inner wall of the drum, aiming to protect the inner wall from wear by the solids in the following way: By the action of the centrifugal forces, a layer of solid particles are deposited, which layer will be out of reach of the helical conveyor and held in position and resisting rotation relative to the drum wall by the strips. By this method, some degree of self-sealing between the helical edge and the fixed layer will be created.

15

The capacity of a decanter centrifuge is mainly depending on two properties: The maximum safe operational rotational speed, and the size of the toroidal volume of liquid and solids contained in the drum.

20

The functional lifetime of a decanter centrifuge is limited by the wear from the solids being conveyed, partly caused by the friction created by the transport action itself, and partly caused by friction between the peripheral edge of the conveyor against the hard and often sharp particles concentrated at high density between the strips during the operation of the centrifuge.

As the flights of the helical conveyor are worn along their edges, the effective volume of separation is reduced accordingly, thus reducing the separation capacity of the centrifuge.

Decanter centrifuges of this type are known to have several different design features and -variations.

The limitations originating from critical frequencies and -vibrations have given rise to several complicated designs, e.g. by letting the helical conveyor be supported by the medium to be treated instead of being supported in rigid 5 bearings.

The Danish patent No. 154540 shows a decanter centrifuge with a helical conveyor comprising a hollow hub with flights having an overall density less than the density of the lighter phase 10 of the medium to be treated. In this way, the influence of the stiffness/weight ratio of the conveyor on the tendency to create vibrations is eliminated, thus making it possible to increase the safe operational speed of the centrifuge.

15 The disadvantages of this arrangement in a centrifuge are that the bearings supporting the conveyor are flexible, thereby making it difficult to transfer the necessary torque and forces to the conveyor from the drive system, thus limiting the conveying capacity. Furthermore, the risk of having 20 deposition of the separated material along the inner wall of the drum in a non-coaxial manner is increased, thus causing the centrifuge to be prone to vibrations.

A large number of inventions have been made to deal with the 25 wear problems, and most of these have attempted to improve the wear resistance in highly loaded wear zones.

The latest approaches have been oriented towards the flights of the conveyor. WO 93/22062 describes a decanter centrifuge 30 with helical flights that have wear resistant rubber protection mounted at their peripheral edge in such a manner that the rubber profile seen in axial section has a different angle to the axis than the flights themselves.

35 The aim of the present invention is therefore to provide a decanter centrifuge of the type mentioned in the opening

paragraph which is safe in operation, which, with mainly the same dimensions, has a larger separation capacity than known before, and which moreover is simple and inexpensive to manufacture.

5

These advantages are obtained through the characteristic properties according to the invention, in which at least the helical flights of the conveyor is manufactured from materials having the same or nearly the same density as the liquid  
10 component of the material to be treated.

As described above, in order to increase the separation capacity of a centrifuge, it is necessary to increase the length and/or the rotational speed of the rotor. A decanter  
15 centrifuge according to the invention will have the option to increase both the length and the rotational speed without sacrificing the technical safety of operation.

The length increase is possible because both the drum and the  
20 conveyor are manufactured from materials that are relatively light and stiff compared to conventional materials, thus improving the ratio of stiffness to weight.

Then hub of the conveyor including the feed inlet for the  
25 sludge is in a preferred embodiment made of the same materials as the helical flights, and the stiffness of the conveyor is increased by a cast-in pipe, reaching from one end of the conveyor to the other between the bearings supporting the conveyor. The combination of the light materials applied for  
30 the hub and flights, and the light and stiff material for the pipe, makes up a conveyor of formerly unknown stiffness to weight ratio, by which a considerable increase of the length and/or a considerable increase of the 1st critical frequency of the conveyor is possible.

35

As a consequence of an increased rotational speed, conventional rotors are prone to increased friction and wear of the helical flights against the inside wall of the drum, resulting in a decreasing lifetime of the centrifuge. This is  
5 primarily caused by the deposited layer of heavy and hard particles between the strips. Further, the pressure between the peripheral edge of the helical flights and the deposited particles is becoming very large, further increasing the resistance and wear.

10

The present invention is distinguished, however, by the fact that this problems does not arise, even at very high rotational speeds. The very characteristic that the helical flights of the conveyor is made from a flexible material and  
15 at the same time is in contact with the inner wall of the drum is preventing the formation of a "protection" layer between the peripheral parts of the flights and the inside of the drum. Thus, no heavy, hard particles can be deposited and retained between the flights and the inside wall of the drum,  
20 and the high pressures creating wear are not at hand. Further, the flexibility of the material of the flights yield to particles that may be trapped, thus preventing excessive wear.

By letting the helical flights be in contact with the inner  
25 wall of the drum, an increase of the operational safety is obtained, as solids matter is no longer permitted to be deposited non-coaxial causing vibrations. By letting the helical flights be composed of an elastomer, and by making them to have an angle relative to the inner wall of the drum  
30 different from 90 degrees, it is secured that the flights, even after some wear at the edge, will be in contact to the inside wall of the drum, and at the same time, the wear of the flights will be decreased considerably, because they are in contact with a smooth wall instead of a layer of deposited,  
35 hard particles.

Furthermore, the separation volume of the centrifuge will be unchanged throughout its lifetime, and the same is valid for its separation capacity.

5 To further decrease the wear of the flights and increase the lifetime of the centrifuge, the profile of the inner wall in sectional view is formed as a gradually converging transition from the cylindrical outline in the liquid outlet end through  
10 in such a way that at every point along the profile, the wear inducing forces are minimized, in particular in the most critical places , i.e. at the feed introduction point.

Furthermore, considerable savings are obtained regarding the  
15 manufacturing, as the conveyor is castable in a simple mould, and machining intensive processes have been eliminated or replaced with modern fibre technology.

In a preferred embodiment, the conveyor hub and the helical  
20 flights are made of only one material. This requires a very large-diameter hub, and thus results in a design with little stiffness, but incorporating all the manufacturing advantages of the invention.

25 Therefore, the preference will normally be to add stiffness to the design by incorporating a stiffener in the form of a pipe connecting the bearings made of a material having great stiffness in relation to its weight. The helical conveyor flights are added as a cast-on feature comprising a material  
30 having a density close to the density of the liquid phase of the material to be treated, causing a buoyancy force on the submerged flights of the same magnitude as the mass forces from the flights' material, when the centrifuge operates.

35 The combined effect of this is that the ratio of mass of the conveyor in submerged condition to the bending stiffness of

the conveyor supported at the bearings is decreased, whereby the first critical vibration frequency of the conveyor is increased.

5 The flights of the conveyor are, for this and other reasons, primarily made from polyurethane.

The helical flights of the conveyor may, in cases where large loads are occurring at the transport of deposited material  
10 along the inner wall of the drum, be reinforced by cast-in plates or lamellas.

Such reinforcing members are preferably made of fibre-reinforced resins in order to reduce the mass/stiffness  
15 ratio of the reinforcement.

Friction and wear are not totally eliminated, and over the time the wear of the peripheral edge of the helical flights is progressing. In order not to lose the advantages attached to  
20 the fact that the flights are in contact with the inner wall of the drum, the flights of one preferred embodiment are formed in such a way that the transporting face of the flights makes an angle to the profile of the inner wall of the drum, seen in axial section, of more than 90 degrees.

25

Accordingly, the helical flights at their innermost position closest to the axis, are formed in such a way that they can pivot around the point of attachment to the hub.

30 By having this feature, wear reduction of the peripheral edge of the flights will cause the flights to pivot outward by action of the centrifugal force, until they reach contact to the inner wall. The angle between the flights and the profile of the inner wall will diminish, but this will not change the  
35 separation capability of the centrifuge to any significance.

The pivoting action will be assisted by the pressure created by the solids material on the transport side of the flights, increasing the sealing action between the flights and the inner wall of the drum.

5

The above characteristics of the present invention are particularly advantageous in the converging part of the decanter centrifuge, where the deposited solids are transported out of the drum. In this part of the centrifuge, a  
10 leakage between the peripheral edge of the flights and the inner wall will cause the solids to slide backwards towards the cylindrical part of the drum and consequently not be conveyed out.

15 This disadvantage is further diminished when the "hill", by which the solids are carried upwards towards the solids' outlet, is formed with a smaller angle of "elevation" in the areas where the centrifugal forces are at maximum, that is at the "foot of the hill" between the cylindrical and converging  
20 parts of the drum.

Therefore, in a preferred embodiment, the profile of the inner wall of the drum is made in three sections along the axis, comprising a first cylindrical part in the liquid outlet end,  
25 a second conical part with a surface angle  $\alpha$ , and a third conical part with a surface angle  $\beta$ , which is greater than  $\alpha$ .

In the following, the invention will be described in detail referring to the attached drawings, where

30

fig. 1 shows an axial section through a helical conveyor for a decanter centrifuge according to the invention,

35

fig. 2 shows an axial section through a drum of a decanter centrifuge according to the invention, and

fig. 3 shows an axial section through an embodiment of a decanter centrifuge according to the invention.

Fig. 1 illustrates a conveyor 2 for a decanter centrifuge 1 according to the invention. The conveyor 2 comprises a conveyor hub 3 and helical flights 4. The conveyor hub 3 and the helical flights 4 are all made of the same flexible material and casted in one piece. The flexible material is polyurethane. Other materials having material properties, i.e. density and wear resistance, with the ability to function at a satisfactory level in a decanter centrifuge according to the invention, may also be applied.

The conveyor hub 3 extends itself from a foremost end 5 to an rear end 6, connected to shafts 7,8 with bearings 9,10. The shafts 7 and 8 are made of steel, and the intermediate stiffener 11 is made from a fibre-reinforced resin material and stretches throughout the conveyor hub 3, comprising an inlet opening 12, protruding through the conveyor hub 3. The rear shaft 8 and its extension 13 are hollow and fastened to the intermediate stiffener 11, and extending from this the hub 3 is also hollow, so that the medium to be treated can be introduced into the interior of the centrifuge through the inlet arrangement 12.

25

The rear, hollow shaft 8 is connected in its free end via a rotating seal 35 to a piping system (not shown) for supply of medium to be treated.

In front of the inlet arrangement 12 the flexible material, by which the conveyor hub is manufactured, is extending throughout the full diameter  $d$  of the hub, along a distance  $a_1$ . Apart from the distance  $a_1$ , the hub 3 is hollow throughout.

35

The helical flights 4 extends from the outer periphery 14 of the conveyor hub 3 to the outer peripheral edge 15. The helical flights 4 form two continuous helixes, extending from the rear end 6 of the conveyor hub to its foremost end 5. The helical flights 4 form an angle relative to the outer periphery 14 of the conveyor hub 3, which angle varies from approximately 90 degrees at the rear end 6 of the conveyor hub, decreasing gradually along the length of the hub 3 to the foremost end 5 of the hub 3.

10

The helical flights are in the embodiment shown able to pivot through a transition point P between the outer periphery 14 of the hub 3 and an inner edge area 16 of the flights 4. An enlarged view shows how the helical flights may be reinforced by the introduction of cast-in stiffeners in the form of lamellas 17.

The helical flights 4 are made as two continuous helixes in order to create ideal dynamical balance. Another number than two may be chosen, provided that proper balancing devices are at hand.

The outer diameter D of the helical flights 4 is constant along a first axial distance  $a_3$  from the rear end of the conveyor, then decreases linearly along a second distance  $a_4$  towards the foremost end 5 of the conveyor hub 3 and further decreases along a third distance  $a_5$ . The conveyor hub likewise decreases from the diameter d towards the foremost end of the hub 3.

30

Fig. 2 illustrates a drum 20 for a decanter centrifuge according to the invention. The drum 20 comprises an inner shell 21 made from steel and an outer shell 22 made from fibre reinforced resin.

35

An rear end 23 of the inner shell 21 ends up in a flange 24 with means 25 for fastening of this flange 24 to another flange (not shown) that provides the bearing support of the rotor in this end. In an opposite foremost end 26 the inner shell 21 is provided with outlet openings 27, 28 for the outlet of the solid phase of the medium to be treated in the centrifuge. The inner shell 21 ends up in the foremost end 26 in a flange 29 with means 30 for fastening this flange to another flange (not shown) which provides the bearing support for this end of the rotor. The inner shell 21 is hollow all through, so that the conveyor 2 can be accommodated into the drum 20.

As mentioned above, the outer shell 22 is made from a fibre-reinforced resin and is intended to provide stiffness and strength to the inner shell 21. On it's inside 31, the inner shell is provided with a wear-resistant surface coating. The inner shell 21 has an inside diameter  $D$  equal to the outside diameter  $D$  of the helical flights 4, and  $D$  is constant along a first axial length  $a_6$ . Along a second axial length  $a_7$  following  $a_6$ , the inner shell 21 has a conical section with a cone angle  $\alpha$  of 4 degrees, and along a third axial length  $a_8$  the inner shell is likewise conical, but with a cone angle  $\beta$  of 8 degrees.

Fig. 3 illustrates the assembled decanter centrifuge 1 according to the invention comprising conveyor 2 and drum 20 as illustrated in figures 1 and 2 subsequently. Further to this, the decanter centrifuge comprises a supporting structure of known type and driving means (not shown). The density of the helical flights 4 are approximately equal to, but slightly larger than the density of the liquid phase of the medium to be treated in the centrifuge, securing that the outer edge of the helical flights 4 is always in contact with the inside surface 31 of the drum 20.

The front side 32 of the helical flights 4 is angled by an angle relative to the inner periphery 31 of the drum 20. During operation, the outer periphery 15 of the helical flights 4 will be worn little by little. The helical flights 4 are fastened to the conveyor hub 3 in such a manner that the angle between the inner edge 16 of the helical flights and the outer periphery 14 of the conveyor hub is changeable. In this way the angle can be changed likewise at a rate according to the rate of wear of the outer edge 15 of the helical flights 4. This provides the ability of the outer edge 15 of the helical flights 4 to be always in contact with the inner periphery 31 of the drum 20. Alternatively, the angle can be changed by introducing angular alterations at other positions along the helical flights 4 than at the inner edge 16 at the point of attachment P.

The process of separation that is performed by the illustrated decanter centrifuge is described below:

20 During operation, the centrifuge rotates along its longitudinal axis at a high speed, which is limited upwards by material strength and critical vibration frequencies of the design.

25 In practical terms, the highest safe speed of operation of a rotor mounted in fixed bearings is between 50% and 70% of the 1st critical frequency of the rotor, depending on the quality of balancing.

30 As an illustration of these conditions, the following equation gives the critical frequency of a rotor in principle:

A shaft simply supported at both ends with even thickness distribution and mass  $m$ , length between supports  $l$ , sectional moment of inertia  $I$  and modulus of elasticity  $E$  will exhibit a 35 1st critical frequency of vibration :

, where  $K$ =constant.

It is easily seen that  $\omega$  will increase with increasing  $E$  or  
5 decreasing  $m$ . Further it may be observed that an increase of  $l$   
will cause a rather large reduction of  $\omega$ .

In real decanter centrifuges, the lowest 1st critical speed is  
exhibited by the conveyor, simply because it has the highest  
10 mass ( $= m$ ) in proportion to its stiffness ( $= E \cdot I$ ).

A large improvement of the conveyor, however, will only reveal  
the next limiting factor, which is the combined 1st critical  
frequency of vibration of the conveyor and drum.

15 As the conveyor is supported by bearings relative to the drum,  
the mass of the conveyor will add to the mass of the drum in  
the equation of 1st critical frequency of the combined rotor  
system, and a reducing of the conveyor's weight will therefore  
20 have a positive effect on the properties of the combined  
rotors as well. It is, however, necessary to improve the  
mass/stiffness relationship for the drum, if the full  
improvement of the conveyor is to be taken into advantage.

25 The centrifuge according to the invention exhibits a  
drastically improvement of the 1st critical frequency of the  
conveyor through the application of modern light materials for  
the helical flights and conveyor hub and the added stiffness  
gained by the introduction of a tube of carbon fibre  
30 reinforced resin as a backbone in the design.

Another important point is that the speed of the drum is  
limited by the strength of the material by which the drum wall  
is manufactured, and a very large proportion of the loads on  
35 the material of the drum wall comes from the weight of the  
drum wall itself.

The other large load component comes from the liquid pressure on the inside of the drum.

5 As an illustration of this, look at the following equation giving the maximum safe speed of operation for a drum with an outer diameter  $D$ , filled with liquid of density  $\sigma \cdot v$ , and the drum material has density  $m$  and maximum allowable stress  $\sigma$  :

10

, where  $K_1$  and  $K_2$  are const.

15 It follows from this that an improvement of the maximum allowable stress  $\sigma$  or an adjacent decrease of the material density  $\rho_m$  will be needed to increase  $\omega$ , and this is exactly the reason behind the design of the drum shell according to the invention: The fibre reinforced material applied for the outer shell has a very advantageous relation between strength and density, resulting in a rotor system of considerably  
20 higher 1st critical frequencies.

A centrifuge of drum diameter 500 mm and a length of 2m will typically be able to reach 5000 rpm.

25 Sludge to be treated in the centrifuge often consists of small particles of solids suspended in a liquid, most often water, which fall towards the bottom of the container surrounding it by gravity.

30 By rotating, the centrifuge is capable of producing a field of gravity many times more forceful than the gravity of earth. In a centrifuge of 500 mm diameter and a speed of 5000 rpm, the centrifugal gravity field at the inside of the drum will be around 7000 times larger than the gravity of earth.

35

Through the feed tube and the seal arrangement 35 the sludge to be treated is introduced along the rotational axis of the centrifuge through the hollow shaft 8, further through the hollow conveyor hub 3 to the inlet opening 12, through which  
5 it is introduced into the interior of the drum. When the centrifuge has been in operation for a time long enough to fill up the ringformed volume 33, the cleaned liquid phase begins to leave the drum by the weir edge 34.

10 At the same time, the conveyor 2 rotates slowly in relation to the drum 3 driven by a transmission (not shown) connected to the conveyor shaft 7. This causes the separated solids phase to be moved by the conveyor, as the helical flights are moving along the inside of the drum 20 "upward" the conical sections  
15 with the angles  $\alpha$  and  $\beta$ , passing the "waterline" at the end of the ringformed volume 33, finally reaching the solids outlet openings 27, from where the solids leave the drum and are collected by not shown chutes.

20 The speed of the conveyor 2 relative to the drum is depending on the pitch of the helical flights and, naturally, on the desired dryness of the solids, and typical values are between 0.5 and 15 rpm.

25 The embodiments shown of conveyor, helical flights and decanter according to the invention may only be considered as examples. Other embodiments having properties within the scope of the claims may be provided. Such other materials than polyurethane can be used, as well as other stiffening members  
30 than tubes and materials for these can be used. The angles  $\alpha$ ,  $\beta$ ,  $\gamma$  and  $\delta$  given by exact values, may take other values as well.

35

## 5 CLAIMS

1. A decanter centrifuge for separation of suspended solids from a liquid medium, comprising a drum and a helical conveyor rotatable mounted therein, c h a r a c t e r i z e d in that  
10 at least the flights of the helical conveyor is being made of materials having the same or approximately the same density as the liquid medium.
2. A decanter centrifuge according to claim 1, c h a r a c t e  
15 r i z e d in that the helical flights is being made of an elastomer with larger density than the liquid medium.
3. A decanter centrifuge according to claims 1 or 2, c h a r a  
c t e r i z e d in that the angle as the helical flights forms  
20 relative to the inside of the drum - seen in axial section - is larger than 90 degrees.
4. A decanter centrifuge according to claims 1, 2 or 3, c h a  
r a c t e r i z e d in having the helical flights fastened to  
25 a conveyor hub of the same or similar material as the flights.
5. A decanter centrifuge according to any of the claims 1 - 4,  
c h a r a c t e r i z e d in that the helical conveyor is  
being mounted onto a drive shaft made from a material having a  
30 larger modulus of elasticity than the material of the flights.
6. A decanter centrifuge according to any of the claims 1 - 5,  
c h a r a c t e r i z e d in that at least a piece of the  
drive shaft surrounded by the helical conveyor is made from  
35 carbon fibre reinforced resin.

7. A decanter centrifuge according to any of the claims 1 - 6, characterized in that the helical flights is being made of a plastic material, e.g. polyurethane.
- 5 8. A decanter centrifuge according to any of the claims 1 - 7, characterized in that the helical flights is being provided with stiffening elements.
9. A decanter centrifuge according to any of the claims 1 - 8,  
10 and in which the liquid outlet end has a larger diameter than the opposite end, characterized in that inside surface of the drum has an axial section formed as a curve of uniform or piece by piece linear curvature having a tangential angle relative to the drum axis at the liquid outlet end  
15 between 0 and 8 degrees, and having a tangential angle  $\alpha$  relative to the drum axis in the opposite end between 8 and 25 degrees.
10. A decanter centrifuge according to any of the claims 1 -  
20 9, characterized in that the drum is comprising an inner and an outer shell, the outer shell made from fibre reinforced resin, and the inner shell made from metal having a wear resistant coating on the inside surface.

25

30

35

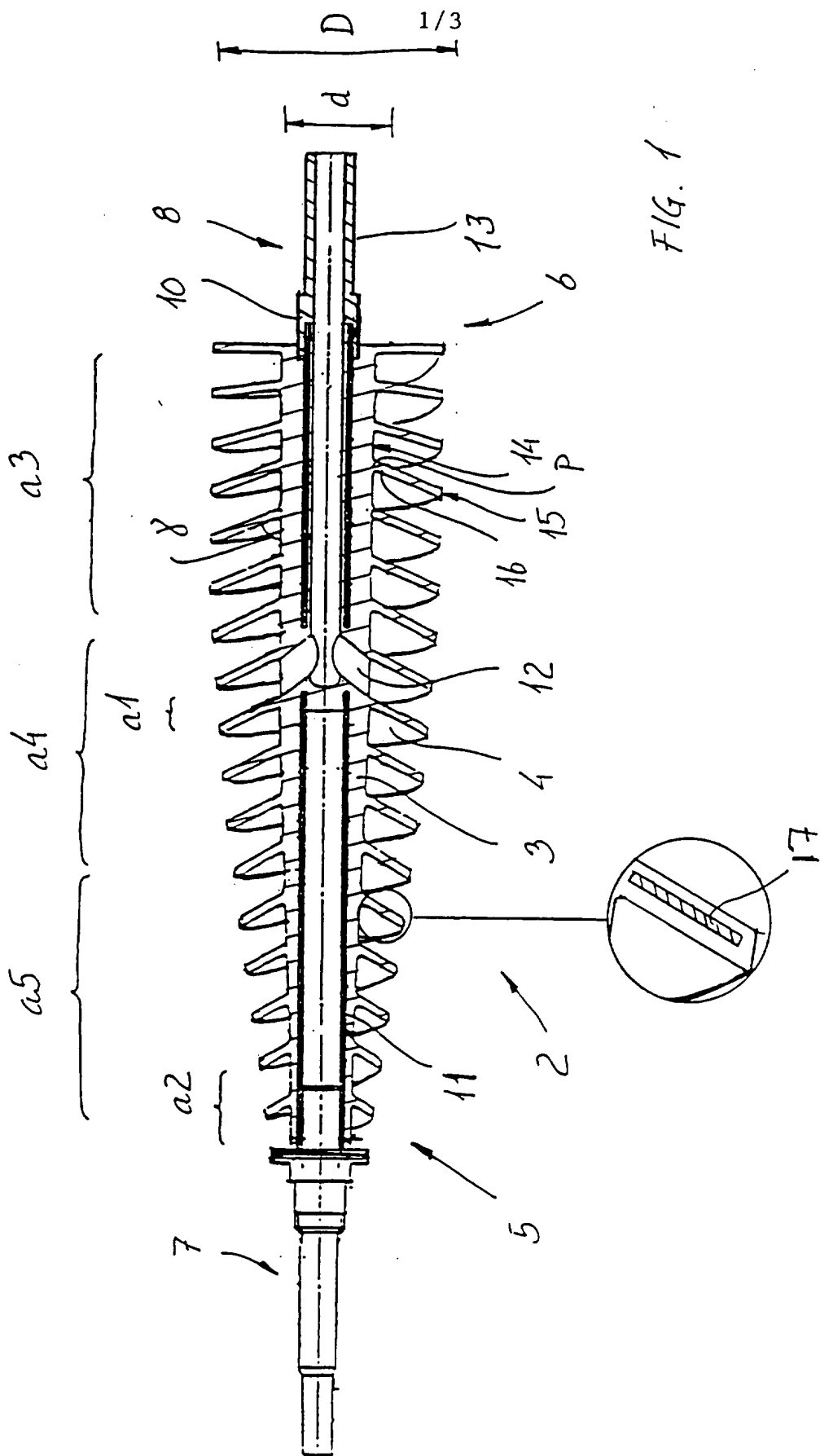


FIG. 1

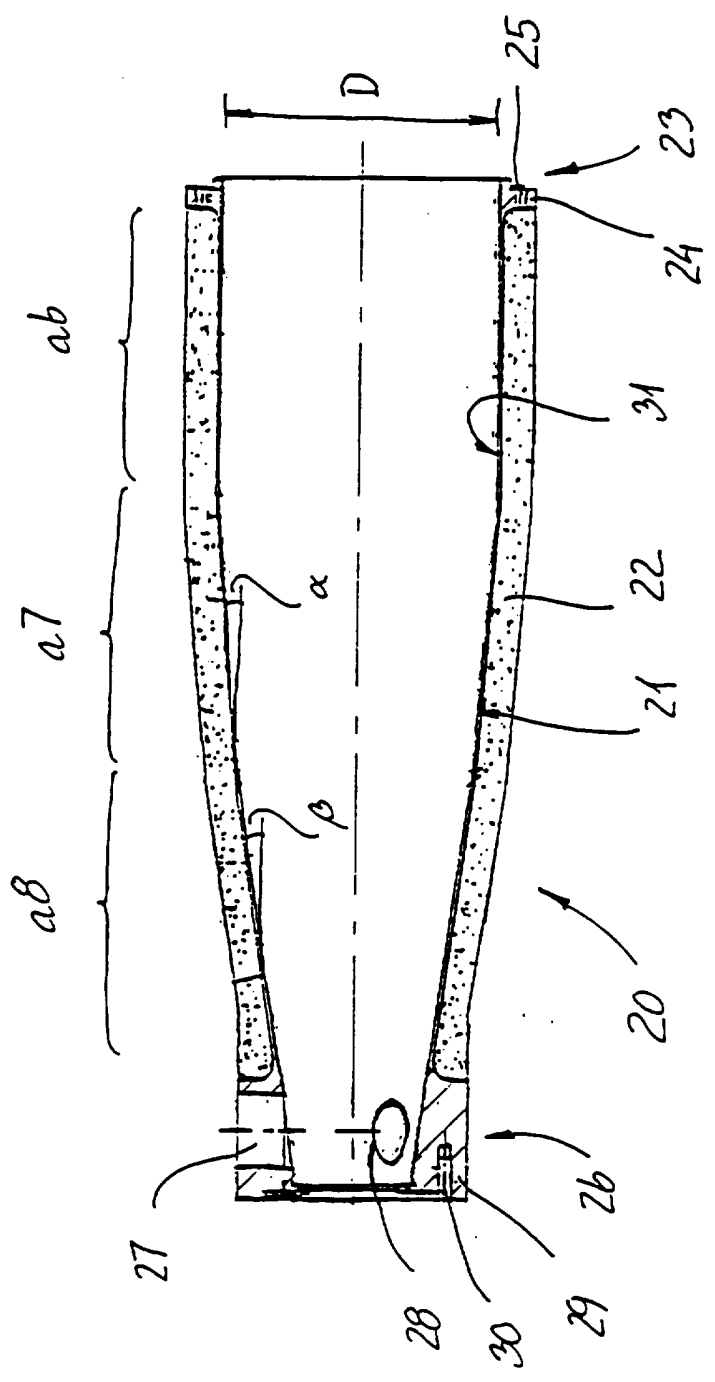


FIG. 2

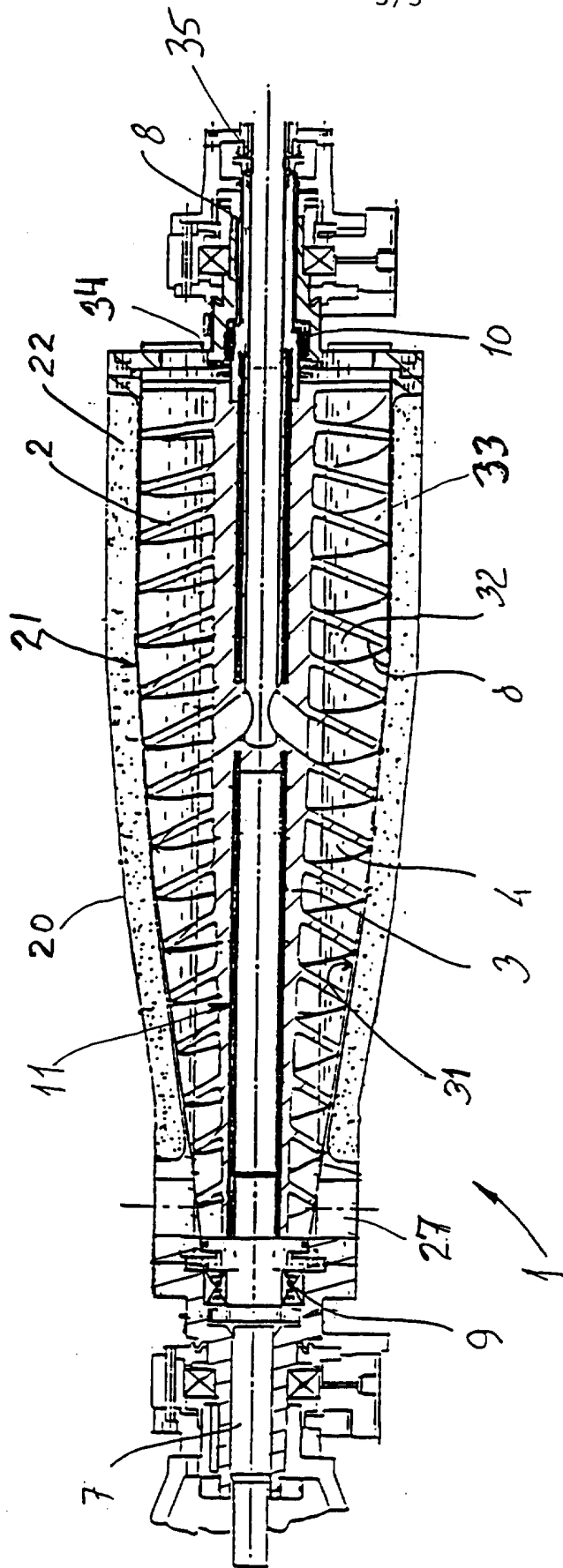


FIG. 3

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/DK 95/00440

## A. CLASSIFICATION OF SUBJECT MATTER

IPC6: B04B 1/20, B04B 3/04

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: B04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4828541 A (NIELS F. MADSEN), 9 May 1989 (09.05.89), column 1, line 5 - line 25, figure 1, claim 1, abstract  --	1,2
A	WO 9322062 A1 (NOXON AB), 11 November 1993 (11.11.93), abstract  -- -----	1

Further documents are listed in the continuation of Box C.

See patent family annex.

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Date of the actual completion of the international search

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**INTERNATIONAL SEARCH REPORT**  
Information on patent family members

05/02/96

International application No.

PCT/DK 95/00440

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