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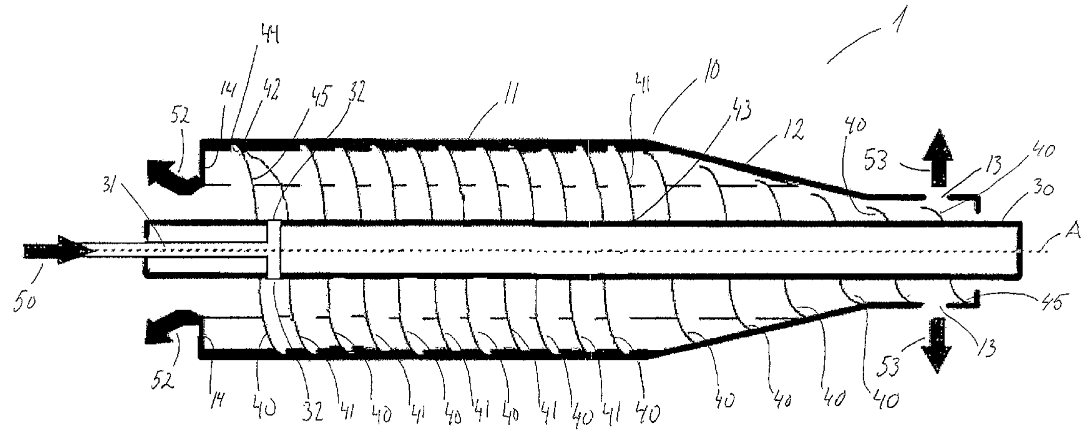

(57) Abstract: A centrifugal decanter comprising a rotatable bowl having a cylindrical part and a conical part; a rotatable, screw conveyor journalled within the bowl coaxially therewith, comprising a shaft and a first helical screw wound around the shaft; a circular weir disposed at an end of said cylindrical part opposite the conical part; an outlet opening from said bowl disposed at the conical part; and an inlet opening to the bowl arranged through the shaft, said bowl and the screw conveyor being rotatable independently with respect to each other wherein the screw conveyor comprises a second helical screw intersecting the first helical screw at a point disposed on the shaft facing the weir and having a terminal end facing the outlet opening.

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CENTRIFUGAL DECANTER

FIELD OF THE INVENTION

The present invention relates to centrifugal decanters of the type having a rotatable bowl, the bowl being rotatable at a first angular velocity, and helical screw conveyor journalled within the bowl coaxially therewith, the helical screw conveyor being rotatable at a second angular velocity.

Large vessels, e.g. tankers, container carriers and cruise ships produce large quantities of sludge oil as a by-product/waste product. A typical production of sludge oil for a large vessel using in the order of 200-250 tons of fuel oil per day is in the order of 3-4 tons per day adding up to a 1,000 metric tons per year. An increasing awareness of the negative consequences of dumping the sludge oil has led to demands from authorities around the world to dispose the sludge oil properly or possibly refine it in order to reuse its useful components. Further, the pure fuel oil content of the sludge oil is in the order of 50 -70%, i.e. 500-700 tons per ship per year. Therefore, the sludge oil represents an economical loss of a considerable size when discarded, but also has a large economical potential if the fuel oil can be recovered from the sludge oil. The value of the fuel oil content of the sludge oil is considered to be in the order of 90,000-126,000 US$ per year in 2005 prices for each ship.

There is therefore a need for an efficient recovering apparatus.

The sludge oil was formerly dumped in the ocean; a practice that is now forbidden globally under international treaties due to its severe environmental impact. Today, sludge oil is landed and disposed of, diluted with fuel oil, and burned, or it is partly regenerated, e.g. in advanced separators. Typically, in the shipping industry vertically oriented centrifugal separators placed on board the ships are applied for separating the component of the sludge oil. However, typically these separators have prohibitively high operational and service/maintenance costs, because they require round-the-clock surveillance and constant manual attendance. Further, such vertical separators, due to their mode of operation, have difficulty in obtaining high dry matter content in their discharges, thus leaving large quantities of waste product, so called super sludge.

Similar considerations are relevant in connection with land-based fuel oil powered power plants, since, in this connection typically even higher amounts of waste products are generated. Therefore there is also in this field considerable potential for more efficient recovering apparatuses.

Also known in the prior art are horizontally oriented centrifugal decanters. Such devices improve the efficiency considerably and reduce the operation costs of the separation of the components of sludge oil.

Essentially centrifugal decanters consist of a bowl, rotatably arranged about a horizontal axis, and a helical screw conveyor, coaxially and rotatably journalled within the bowl.

The bowl usually comprises a cylindrical part and a conical part. Outlet openings are disposed at the terminal end of the conical part in order to lead the heavier components of the separated compound treated in the decanter away. At the opposite end of the decanter, the terminal end of the cylindrical part comprises a weir, over which the lighter components of the treated compound may flow.

The screw conveyor comprises a shaft and helical screw. The outer diameter of the helical screw is adjusted to the inner diameter of the bowl in such a way that a small distance is provided there between in order to allow rotation of the screw conveyor with respect to the bowl.

An inlet passage for the compound to be treated is arranged within the shaft, the inlet passage terminating in openings through the shaft-wall where the compound to be treated can enter the decanter bowl.

The bowl and the screw conveyor are arranged in such a way that they can rotate coaxially but independently of each other. During use, the bowl is rotated at a first angular velocity in such a way that the centrifugal acceleration is greater than the acceleration due to gravity, causing a compound to be treated in the decanter and fed through the inlet passage to be pressed against the inner side of the bowl. High-density particles and materials will precipitate closest to the wall and lighter density particles on top of these. By continuously feeding the compound to be treated into the bowl, the internal level of compound inside the bowl will rise, until the level reaches the weir head, and the lighter-density material will flow over the weir and can be led from the decanter.

The helical screw conveyor is rotated at a second angular velocity different from the angular velocity of the bowl, the first angular velocity. The relative rotation between the bowl and the screw conveyor causes the high-density material precipitated closest to the wall to be transported towards the conical part of the bowl and outlet openings, due to the pitch of the screw. The weir is arranged at a larger diameter than the outlet openings.

Consequently, the transported material will be drawn above the surface of the compound inside the bowl and up the conical part of the bowl and out the outlet openings.

Thus the centrifugal decanter separates the high-density components from the low-density components of the compound fed into the decanter. If the compound is a liquid containing solids, the concentration of solids in the liquid compound exiting the outlet openings will be much higher than in the compound entering the decanter, and correspondingly the liquid compound flowing over the weir will have a much lower concentration of solid parts than the compound entering the decanter.

The traditional horizontal centrifugal decanters, however, have some disadvantages. At the inlet provided in the shaft, where the compound to be treated is injected at a certain pressure, the injected compound will splash into the already precipitated and separated compound which is in the process of being transported towards the outlet opening and/or the weir, thereby causing a mixing of the components of the compound, which will reduce the efficiency of the separation process. The present invention is based on the realization that this problem constitutes a limiting factor to the efficiency of the separation process of traditional horizontal centrifugal decanters.

OBJECT OF THE INVENTION

It is an object of the present invention to provide a centrifugal decanter that solves the problems of the prior art, and improves the efficiency of the separation process. It is a further object to provide an alternative centrifugal decanter. It is yet another object of the present invention to provide a centrifugal decanter that can be applied in the field of sludge oil regeneration. It is yet a further object to provide a centrifugal decanter that can extract from sludge oil, a fuel oil component pure enough to be utilized in ships engines to propel e.g. a ship. It is a further object to provide a centrifugal decanter efficient enough to separate in general a liquid-liquid solution. It is a further object of the invention to provide a centrifugal decanter having an increased capacity.

SUMMARY OF THE INVENTION

The object of the invention is achieved by a centrifugal decanter comprising a rotatable bowl having a cylindrical part and a conical part; a rotatable screw conveyor journalled within the bowl coaxially therewith, comprising a shaft and a first helical screw wound around the shaft; a circular weir disposed at an end of said cylindrical part opposite the conical part; an outlet opening from the bowl, disposed at the conical part; and an inlet opening to the bowl, arranged through the shaft, said bowl and the screw conveyor being independently rotatable with respect to each other wherein the screw conveyor comprises a second helical screw intersecting the first helical screw at a point disposed on the shaft facing the weir and having a terminal end facing the outlet opening.

Thus, it has been found that with a centrifugal decanter according to the invention, the amount of dry component removed from the sludge oil is increased by more than 50 %, thus considerably reducing the amount of super sludge. An increase in dry component recovery is also found for other treated liquids over the prior art decanters. The capacity of the centrifugal decanter thus being increased further provides for a more flexible centrifugal decanter in such a way that the same capacity can be obtained by a much smaller decanter with respect to a prior art decanter, or if using the same size decanter, a much higher capacity is achieved.

In a preferred embodiment the second helical screw extends over the entire length of the cylindrical part of the bowl. Thereby, the length of the path over which the liquid to be treated is allowed to separate, is optimised.

In a further preferred embodiment the inlet openings are disposed in the end of the shaft facing the weir.

Alternatively the screw conveyor comprises two or more additional helical screws.

Preferably the bowl is rotatable at a first angular velocity, and the screw conveyor is rotatable at a second angular velocity.

The centrifugal decanter thereby achieved is so efficient that it is specifically applicable for sludge oil separation.

The invention further concerns an installation comprising a centrifugal decanter, an engine, and a fuel oil tank wherein the installation is adapted to lead fuel oil regenerated from sludge oil in the centrifugal decanter to the fuel oil tank. Preferably, the installation is disposed in a ship.

However, the installation may also be disposed in a land-based power station.

DRAWINGS

In the following the present invention will be described in further detail with reference to the drawings in which

- Fig. 1A shows a section through a prior art centrifugal decanter,
- Fig. 1B shows in principle the transport mechanism of the prior art centrifugal decanter shown in Fig. 1A,
- Fig. 2 shows a section through a centrifugal decanter according to an embodiment of the invention,
- Fig 3A shows a partial side view of an embodiment of a screw conveyor of a centrifugal decanter according to the invention, and
- Fig. 3B shows in principle the transport mechanism of the centrifugal decanter shown in Fig. 2 and 3A

DETAILED DESCRIPTION OF THE INVENTION

In order to introduce the field of the invention, initially a brief description of a prior art centrifugal decanter 1 as described in the introduction above is provided with reference to Figs. 1A and 1B. Fig. 1A shows in a principle sketch a section through a prior art centrifugal decanter 1, comprising a decanter bowl 10, hereinafter termed: bowl; and a screw conveyor 20, comprising a hollow shaft 30 and a helical screw 40 indicated by the sinuous-like curves in the figure. An inlet passage 31 for the compound to be treated is arranged within the shaft 30, the inlet passage 31 terminating in openings 32 through the shaft-wall where the compound to be treated can enter the decanter bowl 10.

The bowl 10, comprising a cylindrical part 11 and a conical part 12, has outlet openings 13 disposed at the terminal end of the conical part 12. A barrier wall or weir 14 is disposed at the opposite end of the decanter 1, i.e. the terminal end of the cylindrical part 11.

The compound to be treated, e.g. sludge oil, is injected from e.g. a tank (not shown) to the inlet passage 31 indicated by the arrow 50, and into the bowl 10 through the inlet openings 32 as indicated by the arrows 51.

As described in the introduction, the outer diameter of the helical screw 40 is slightly smaller than the inner diameter of the bowl 10 such that a small distance is provided there between. When the compound to be treated is injected into the rotating bowl 10, the compound level quickly exceeds the small distance between the helical screw 40 and the bowl 10. Thereby a helical channel will be formed along the inner side of the bowl defined by the helical screw 40. In Fig. 1B this channel is illustrated as a stretched-out channel 60. When the level of the compound to be treated exceeds the height D of the weir 14, i.e. the radial distance from the inner diameter of the bowl 10 to the inner rim or circumference of the circular weir or end wall 14, the compound will start to flow over the weir 14 as indicated by arrow 52 in Figs.1 A and 1B. Due to the rotation about the central axis A of the bowl 10 the compound will be at least partly separated in such a way that the high-density components are now positioned close to the inner wall of the wall, and the lighter-density components will be precipitated closer to the shaft 30, due to the centrifugal force. In Fig. 2B the high-density material is indicated by the dark area 61 in the bottom of channel 60 and the light-density material is the lightly shaded material 62 in the top part of the channel 60. It will be appreciated that the light-density material 62 will flow over the weir 14.

Correspondingly, the high-density material precipitated at the bottom of channel 60 will be influenced by the rotating screw conveyor 20 in such a way that the material will be transported towards the outlet opening 13 (see Fig. 1A), which in Fig. 1B is indicated by the rightmost end of the sloped part of the channel 60. The continuous transportation of high-density material will force the material to be expelled through the openings 13 as indicated by arrows 53.

As can be appreciated from Fig. 1B, the injection of the compound into the bowl 10 (indicated by arrow 51) into the channel 60 at a certain pressure will create turbulence in material in the channel 60 and at least partially counteract the separation of the constituent components of the compound.

Turning now to the invention, in the following description of Figs. 2, 3A and 3B, like references will be used for like part of the decanter 1 shown in Fig. 1A and 1B, although the details may differ.

In Fig. 2 a centrifugal decanter 1 according to one embodiment of the invention is shown. The centrifugal decanter 1 comprises a bowl 10 and a screw conveyor 20. The bowl 10, like in the prior art described above, comprises a generally cylindrical part 11 and a conical part 12, a weir 14 arranged at the free end of the cylindrical part 11. Further, the bowl 10 comprises outlet openings 13 arranged at the conical part 12 of the bowl 10.

In Fig. 3A the bowl has been almost entirely cut out in order to show details of the screw conveyor 20. Thus the bowl in the figure is only represented by a weir 14, which constitutes the end wall of the cylindrical part of the bowl 10.

The screw conveyor 20 comprises a hollow shaft 30 and a first helical screw 40 wound around and along said shaft 30, as does the shaft 30 shown in Fig. 1A, having a first end 44 disposed at the end of the shaft 30 facing the weir 14, and a second, terminal end 45 disposed on the shaft facing the free end of the conical part 11 of the bowl 10. However, the screw conveyor 20 according to the invention comprises at least one further helical screw. In the embodiment shown in Fig. 3A the shaft 30 has one additional helical screw, second helical screw 41. The second helical screw 41 is arranged on the shaft 30 in such a way that at the terminal end of the shaft 30 closest to the weir 14 (at the left hand side of Fig. 3A), the two helical screws 40, 41 intersect or start their windings about the shaft 30 at a common point 42. The second helical screw 41 is, as the'first helical screw 40 wound around and along the shaft 30. But, where the first helical screw 40 extend over the entire length of the part of the shaft 30 disposed inside the bowl 10 including the conical part 12, the second helical does not. Preferably, the second helical screw 41 extend along the length of the shaft 30 disposed within the cylindrical part 11 of the bowl 10 only as shown in Fig. 3A. Preferably, the second helical screw 41 does not extend along shaft 30 at the part of the shaft 30 disposed in the conical part 12 of the bowl 10. The second helical screw 41 terminates at a point 43. Seen from the end of the shaft 30 disposed at the weir-end of the bowl 10, the first helical screw 40 is the first of the helical screws 40, 41 to start it's windings around the shaft 30. The second helical screw 41 departs or starts from the first helical screw 40 on a surface 45 thereof facing towards the conical end of the bowl 10. Thereby, a path or channel 60a opens from the point 42, which will be further described below. Preferably, and as shown in Figs. 2 and 3A the second helical screw departs from the first winding of the first helical screw 40 as seen from the weir-end of the decanter bowl 10.

In the embodiment shown in Fig. 3A the second helical screw 41, as mentioned extends along the entire length of the shaft 30, that is disposed within the cylindrical part 11 of the bowl 10, the first end of the second helical screw 41 starting at the weir 14 and having it's terminal end 43 at the passage between the cylindrical and conical parts 11, 12. Thus, the length of the channels 60a and 60b, see below, obtains it maximum length. However, in the general case the second helical screw 41 does not need to extend all the way from the weir 14 to this passage. The second helical screw 41, however, must originate at an intersection 42 of the first and second helical screws 40, 41 that is facing the weir end 14 of the bowl 10 and the terminal end 43 of the second helical screw must face the conical end 12 of the bowl 10. The terminal end 42 of the second helical screw must be disposed closer to the weir 14 than the terminal end 45 of the first helical screw 40.

An inlet passage 31 for the compound to be treated is arranged within the shaft 30, the inlet passage 31 terminating in openings 32 through the shaft-wall where the compound to be treated can enter the decanter bowl 10 as indicated by the arrows 51 (see Fig. 3A). The compound to be treated, e.g. sludge oil, is injected from e.g. a tank (not shown) to the inlet passage 31, as indicated by the arrow 50 (see Fig. 2).
Preferably the inlet openings 32 are disposed in the shaft close to the point 42 where the helical screws 40, 41 intersect in the channel 60a opened between the first and second helical screws 40, 41.

The bowl 10 and the screw conveyor 20 are arranged in such a way that they can rotate coaxially but independently of each other. During use, the bowl 10 is rotated at a first angular velocity, ω, in such a way that the centrifugal acceleration of the decanter bowl 10 is greater than the acceleration due to gravity, g, causing a compound to be treated in the decanter and fed through the inlet passage 31 to be pressed against the inner side of the bowl 10, i.e. the angular velocity must comply with the following relation $r\omega^2 > g$, where r is the radius of the bowl 10. High-density particles and materials will precipitate closest to the inner wall of the bowl, and lighter density particles on top of these. By continuously feeding the compound to be treated into the bowl 10, the internal level of compound inside the bowl 10 will rise, until the level reaches the weir head D, and the lighter-density material will flow over the weir 14 and can be led from the decanter 1, which is indicated in Fig. 2 and 3A by arrows 52.

The helical screw conveyor 20 is rotated at a second angular velocity different from the angular velocity of the bowl 10, the first angular velocity. The relative rotation between the bowl and the screw conveyor 20 causes the high-density material precipitated closest to the wall of the bowl 10 to be transported towards the conical part 12 of the bowl 10 and outlet openings 13, due to the pitch of the helical screws 40, 41. The weir 14 is arranged at a larger diameter (with respect to axis of rotation A of the decanter 1) than the outlet openings 13. Consequently, the transported material will be drawn above the surface of the compound inside the bowl and up the conical part 12 of the bowl 10 and out the outlet openings 13.

Typically, first and second angular velocities would be 3250 rpm (rounds per minute) and 3260 rpm, respectively. These values are only exemplary. The ratio between the two angular velocities should preferably be in the interval of 0.980 and 0.999 in order to create a slow flow of high-density materials towards the outlet openings. The lower limit of the angular velocities are, as described above, determined by the relation $r\omega^2>g$, and the upper limit is determined by material properties of the constituent parts of the centrifugal decanter, because the higher the angular velocity the higher the forces on the bearings holding the rotating parts of the centrifugal decanter. However, for most practical purposes the angular velocities should probably be kept below 7000 rpm. It should be noted that the aforementioned angular velocities could be reversed in such a way that the angular velocity of the bowl 10 would be higher than the angular velocity of the screw conveyor 20. This would require that also the pith of the helical screws 40, 41 would be reversed. Thus the centrifugal decanter 1 separates the high-density components from the low-density components of the compound fed into the decanter 1. If the compound is a liquid containing solids, the concentration of solids in the liquid compound exiting the outlet openings 13 will be much higher than in the compound entering the decanter 1, and correspondingly the liquid compound flowing over the weir 14 will have a much lower concentration of solid parts than the compound entering the decanter 1.

As for the prior art centrifugal decanter 1 described with respect to Fig. 1A and 1B, the outer diameter of the helical screws 40, 41 is slightly smaller than the inner diameter of the bowl 10 in such a way that a small distance is provided there between. When the compound to be treated is injected into the rotating bowl 10, the compound level quickly exceeds the small distance between the helical screws 40, 41 and the inner wall of bowl 10. Thereby a set of helical channels will be formed along the inner side of the bowl 10 defined by the helical screws 40, 41.

In Fig. 3B this set of channels is illustrated as a stretched-out (rather than helical) channel system 60a, b, c. When the level of the compound to treated exceeds the height D of the weir 14, i.e. the radial distance from the inner diameter of the bowl 10 to the inner rim or circumference of the circular weir 14 or end wall, the compound will start to flow over the weir 14 as indicated by arrow 52 in Figs. 2, 3A and 3B. Due to the rotation of the bowl 10 about the central axis A the compound will be at least partly separated in such a way that the high-density components are now positioned close to the inner wall of the wall, and the lighter-density components will be precipitated closer to the shaft 30, due to the centrifugal force, as described above. In Fig. 3B the high-density material is indicated by the dark area 61 in the bottom of channel 60 and the light-density material is the lightly shaded material 62 in the top part of the channel 60.

It will be appreciated that the light-density material 62 will flow from the inlet openings 32, represented by arrow 51 in Fig. 3B, through one leg 60a of the channel system from the point 42 where the helical screws 40, 41 intersect and pass down the second leg 60b of the channel system that branch of at the point 43 where the second helical screw 41 ends.

The light-density material is prevented from moving down the third leg 60c of the channel system representing the channel formed between the first helical screw 40 and inner wall of the conical part 12 of the bowl 10 due to the slope of the conical inner wall. At the terminal end of the leg 60b corresponding to a location at the weir 14 in Fig. 3B the light-density material will flow over the weir 14, as indicated by arrow 52 in Fig. 3B.

Correspondingly, the high-density material precipitated at the bottom of the channel system 60a, b, c will be influenced by the rotating screw conveyor 20 in such a way that the material will be transported towards the outlet opening 13, which in Fig. 3B is indicated by the rightmost end of the sloped channel leg 60c. The continuous transportation of high-density material will force the material to be expelled through the openings 13 as indicated by arrow 53.

It will be appreciated from Fig. 3B that the high-pressure inlet of the compound (arrow 52) at the inlet openings 32 with this construction will not create a turbulence in precipitated compound. The path over which the precipitated compound in the bowl 10 is left undisturbed is thus optimised having the inlet openings disposed at the end of the shaft 30 disposed at the weir-end of the bowl 10, and the second helical screw 41 extending over the entire length of the cylindrical part 11 of the bowl 10, as is the preferred embodiment shown in Figs. 3A and 3B.

However, the turbulent mixing will be avoided as long as the inlet openings 32 are disposed inside the channel 60a, and could thus in other embodiments be situated anywhere therein, i.e. between the intersection point 42 and the terminal point 43. Also the second helical screw 41 (and thereby channel 60a) need not – in alternative embodiments - extend over the entire length of the part of the shaft that is disposed inside the cylindrical part 11 of the bowl 10.

Further, the above-described embodiment of the centrifugal decanter 1 has only a single additional helical screw 41. However, in alternative embodiments the centrifugal decanter may comprise two or more additional helical screws (not shown) thus forming two or more additional channel legs. Each of these should comprise inlet openings 32 from the inlet passage 31 in the shaft 30.

CLAIMS

1. A centrifugal decanter (1) comprising
   - a rotatable bowl (10) having a cylindrical part (11) and a conical part (12);
   - a rotatable screw conveyor (20) journalled within the bowl coaxially therewith, comprising a shaft (30) and a first helical screw (40) wound around the shaft (30);
   - a circular weir (14) disposed at an end of said cylindrical part (11) opposite the conical part (11);
   - an outlet opening (13) from the bowl (10), disposed at the conical part (11); and
   - an inlet opening (32) to the bowl, arranged through the shaft (30),

said bowl (10) and the screw conveyor (20) being independently rotatable with respect to each other, wherein the screw conveyor (20) comprises a second helical screw (41) wound around the shaft (30), a first end of said of said second helical screw (41) intersecting the first helical screw (40) at a point (42) disposed on the shaft (30) facing the weir (14), and a terminal end (43) of said second helical screw (41) facing the outlet opening (13).

2. A centrifugal decanter (1) according to claim 1 wherein the second helical screw (41) extend over the entire length of the cylindrical part (11) of the bowl (10).

3. A centrifugal decanter (1) according to claim 1 or 2 wherein the inlet opening (32) is disposed in the end of the shaft facing the weir (14).

4. A centrifugal decanter (1) according to any one of claims 1-3 wherein the screw conveyor (20) comprises two or more additional helical screws.

5. A centrifugal decanter (1) according to any one of claims 1-4 wherein the bowl (10) is rotatable at a first angular velocity, and the screw conveyor (20) is rotatable at a second angular velocity.

6. Use of a centrifugal decanter (1) according to any one of the previous claims 1-5 for sludge oil separation.

7. An installation comprising a centrifugal decanter (1) according to any one of the previous claims 1-5, and further comprising an engine, a fuel oil tank wherein the installation is adapted to lead fuel oil regenerated from sludge oil in the centrifugal decanter (1) to the fuel oil tank.

8. An installation according to claim 6 wherein the installation is disposed in a ship.

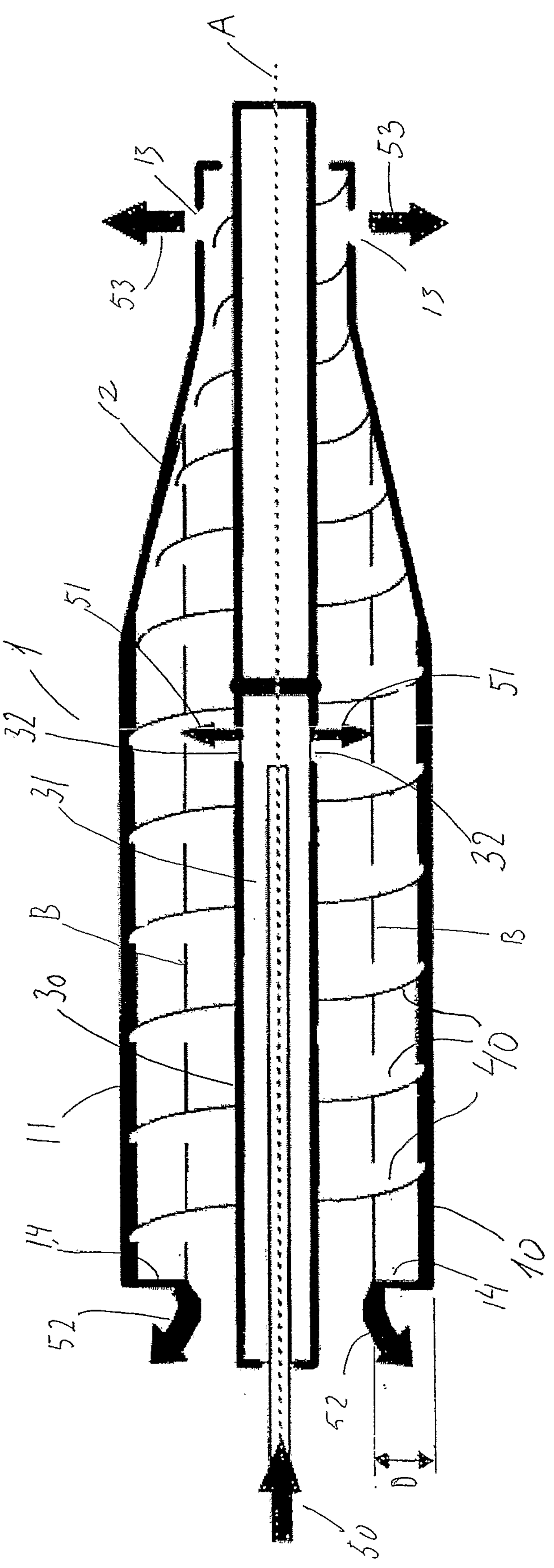

Fig. 1A Prior Art

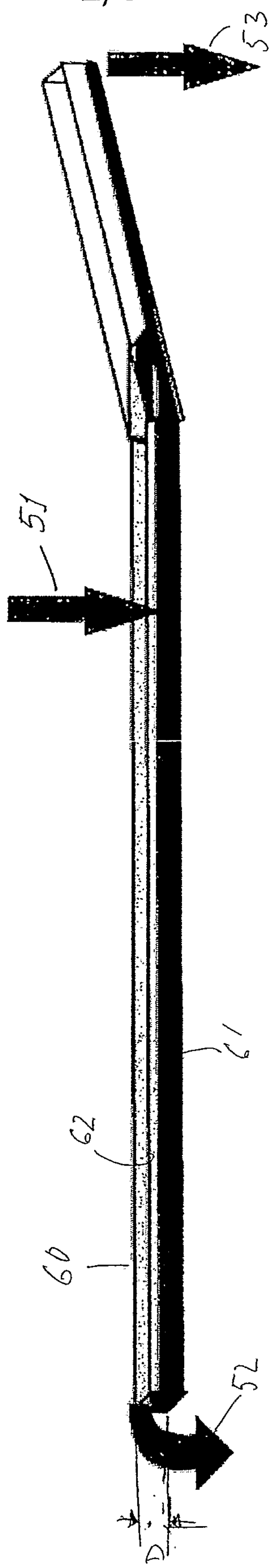

Fig. 1B Prior Art

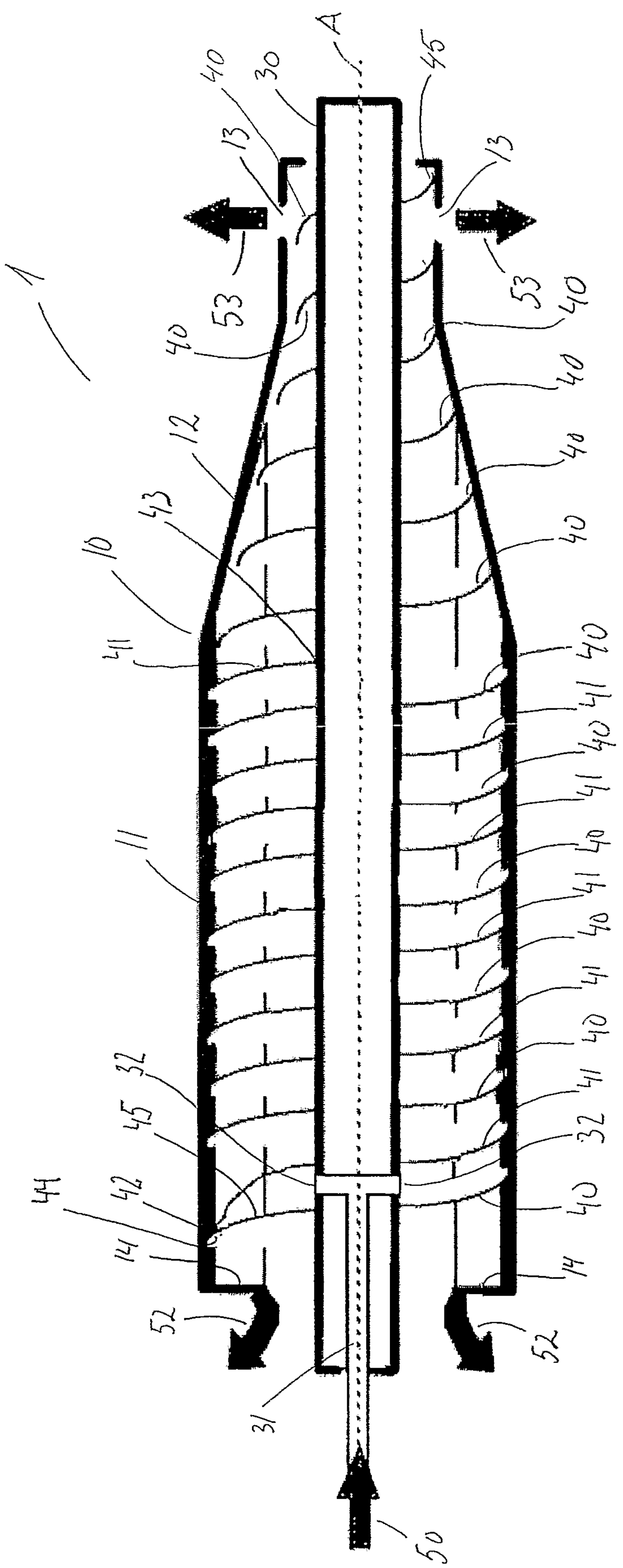

Fig. 2

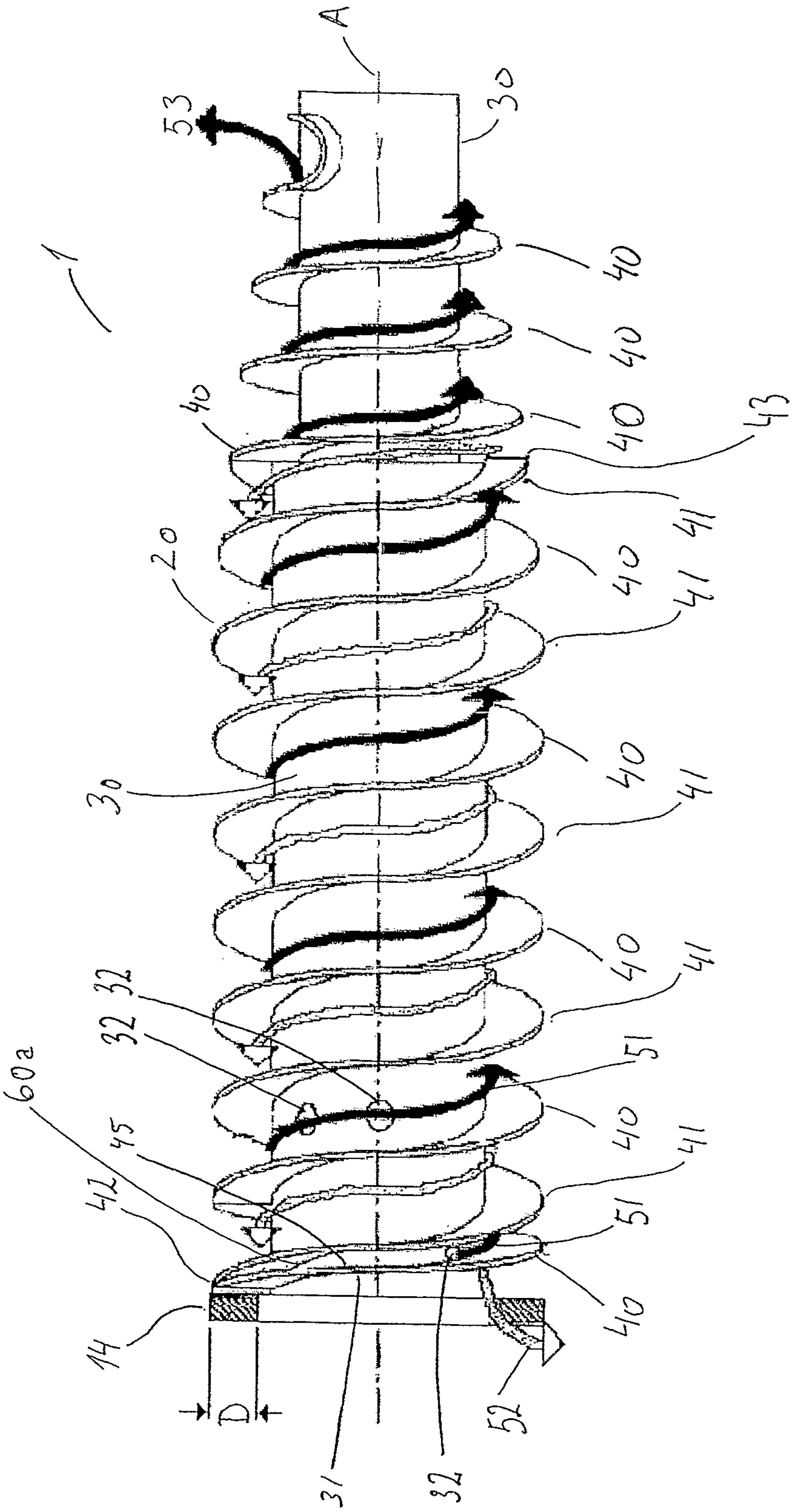
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Fig. 3A

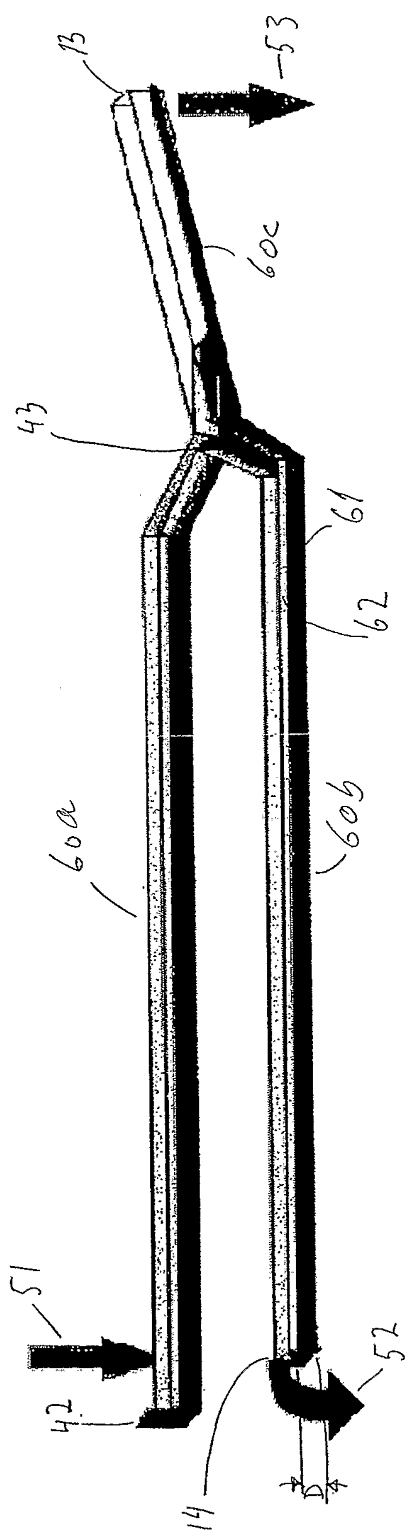

Fig. 3B