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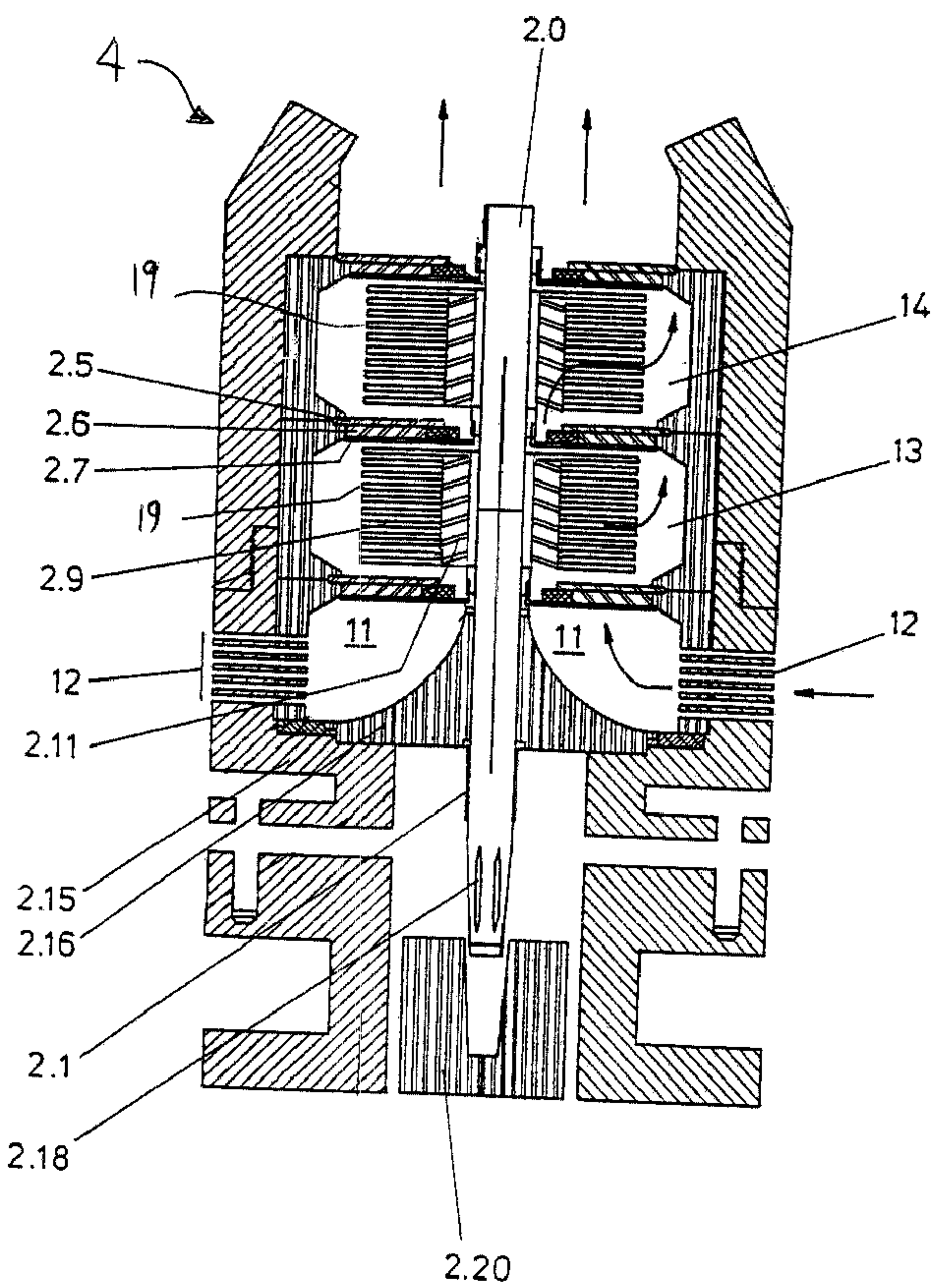


(57) Abrégé/Abstract:
A pump/separator apparatus is disclosed for pumping a viscous fluid mixture upwardly from an underground location and for carrying out at least partial separation of the mixture into separate component parts or phases. The apparatus comprises a cylindrical housing 2.15 having an intake 12 at or near its lower end to receive the viscous fluid mixture, and an upper discharge

(57) **Abrégé(suite)/Abstract(continued):**
end to which the fluid can be pumped. An inner impeller rotatably mounted in the housing 2.15 generates a spirally upwardly moving column of fluid which rotates around the axis of the housing 2.15 and thereby induces inward flow of the mixture through the intake 12. A stack of rotary disks 2.9 is arranged in the housing 2.15 in a separation zone 13 located above an intake chamber 11, and in which the disks 2.9 are spaced apart from each other and serve to assist in guiding the flow of fluid upwardly through the housing to the discharge end and to assist in separation of the fluid into at least some of its separate parts or phases.

ABSTRACT

A pump/separator apparatus is disclosed for pumping a viscous fluid mixture upwardly from an underground location and for carrying out at least partial separation of the mixture into separate component parts or phases. The apparatus comprises a cylindrical housing 2.15 having an intake 12 at or near its lower end to receive the viscous fluid mixture, and an upper discharge end to which the fluid can be pumped. An inner impeller rotatably mounted in the housing 2.15 generates a spirally upwardly moving column of fluid which rotates around the axis of the housing 2.15 and thereby induces inward flow of the mixture through the intake 12. A stack of rotary disks 2.9 is arranged in the housing 2.15 in a separation zone 13 located above an intake chamber 11, and in which the disks 2.9 are spaced apart from each other and serve to assist in guiding the flow of fluid upwardly through the housing to the discharge end and to assist in separation of the fluid into at least some of its separate parts or phases.

"PUMP/SEPARATOR APPARATUS FOR VISCOUS LIQUIDS"

This invention relates to a pump/separator apparatus for handling viscous liquids, such as heavy oil bitumen which is being extracted from an underground oil-bearing stratum.

The extraction of heavy oil bitumen from an underground "reservoir" presents significant handling problems, by reason of the high viscosity of bitumen, and the presence of other liquids, gases and even solid particles in admixture with the bitumen. The pumping/separation action is presently carried out using bladed impellers or vane-type pumps, which pump the mixture to surface installations at which separation of the mixture into its constituent parts can take place.

In view of the high viscosity of bitumen, conventional pumps and separators require steam invention to lower the viscosity of the bitumen and therefore make it easier to handle, and to be pumped. Then, with the aid of the lifting surfaces on the blades, the bituminous mixture can be lifted to the surface, and after evacuation to a secondary location, required separation processes can take place.

These conventional pumps are subject to blade impingement of solids when abrasive materials are present in the pumped fluid mixture, which is often the case. The resulting erosion of the impeller blades causes the blade pump to be subject to increasing inefficiencies, due to worn impellers and significant down time for repairs and replacements, resulting in high operating and maintenance costs, and incipient pump failures. There is also an additional cost by reason of double-handling of the bituminous mixture, namely first the pumping action to raise the mixture to the surface, and secondly a subsequent separation into the component parts, namely solids, liquids and gases.

One of the most difficult problems facing conventionally bladed pumps is cavitation. This phenomenon occurs when the suction pressure on the pump inlet drops below the vapour pressure at the inlet temperature of the fluid being pumped. Given the temperature and density of a typical heavy oil bitumen, this can be a common occurrence. The resulting vapour bubbles or pockets in the heavy oil bitumen are impacted by the lifting surfaces of the impeller blades, and these pockets collapse, with the result that the fluid bitumen slurry flows slowly into the void left by the collapsed pocket. The resulting implosion wears away at the surface of the impeller blade, causing rapid erosion of the impeller and significant deterioration in the pump performance. It also causes severe discharge fluctuations, which may damage sensitive downstream equipment. Unchecked, continual cavitation can cause the pump to lo~~o~~se its "prime", or to trip safety sensors which shut-off the pumping action completely.

The present invention seeks to provide an improved pump/separator apparatus for handling viscous liquids, such as heavy-oil bituminous fluid mixtures, and which overcomes the limitations of conventional pumps having lifting surfaces and requirement for secondary handling to separate the constituent components.

According to the invention there is provided a pump/ separator apparatus for pumping a viscous fluid mixture upwardly from an underground location and for carrying out at least partial separation of the mixture into separate component parts or phases during the pumping operation, said apparatus comprising:

a substantially cylindrical housing having an intake at or near its lower end to receive the viscous fluid mixture, and an upper discharge end; ~~and~~ and

an inner impeller rotatably mounted in the housing, said impeller rotatably mounted in the housing, said impeller having a radial extent which is less than the radial extent of the internal chamber defined by the housing, and said impeller being rotatable around the axis of the housing in order to generate a spirally upwardly moving column of fluid which thereby induces inward flow of the fluid mixture through the intake; ~~and~~

and a stack of disks arranged in the housing in a separation zone located above an intake chamber defined in the housing adjacent to the intake, said disks being spaced apart from each other with respect to the axis of the housing, and serving to guide the flow of fluid upwardly through the housing and to assist in separation of the fluid into at least some of its separate component parts or phases.

Preferably, the intake comprises a circumferential inlet formed in the wall of the housing, and a stack of inlet vanes is preferably mounted in the intake chamber in the housing.

The inlet vanes may comprise a Set of generally planar and parallel vanes which are spaced apart from each other with respect to the axis of the housing.

The pump/separator apparatus according to the invention may comprise a multi-component assembly, including more than one pump, each having its own respective electric drive motor coupled therewith.

Preferably, a diffuser is arranged in the housing to separate the intake chamber from the separation zone. Also, the separation zone may be sub-divided by a further diffuser, and with a respective stack of rotary disks in each sub-divided portion.

Preferred embodiment of pump/separator apparatus according to the invention will now be described in detail by way of example only, with reference to the accompanying drawings, in which:

Figure 1a is a diagrammatic illustration of a combined disk pump/separator apparatus according to the invention, the apparatus being shown enlarged in Figure 1b;

Figure 2 illustrates schematically a multi-pump and drive motor assembly according to a further embodiment of the invention;

Figure 3 is an enlarged and schematic illustration of the internal components of a pump of the apparatus;

Figure 4 is an enlarged view, similar ~~to~~and expanded from Figure 3, and illustrating the path of flow of a viscous fluid mixture through the pump stage of the apparatus;

Figure 5a, b and c ~~Show~~show respectively a perspective view viewed from the fluid intake, plan view and elevational view of a further embodiment of pump for use in the apparatus; and

~~Figure 6 is a~~Figures 6a and b are schematic illustrations of the path of flow of bituminous heavy oil through a disk diffuser of a pump of the apparatus in exploded view and assembled respectively.

Referring now to the drawings, there will be described embodiments of pump/separator apparatus according to the invention for pumping a viscous fluid mixture upwardly from an underground location and for carrying out at least partial separation of the mixture into separate component parts or phases during the pumping operation. In general terms, the apparatus comprises a cylindrical housing 2.15 having an intake 12 at or near its lower end to receive the viscous fluid mixture, and an upper discharge end to which the fluid can be pumped. There is an inner impeller rotatably mounted in the housing and which is operable to generate a spirally upwardly moving column of fluid which rotates around the axis of the housing, and thereby induces inward flow of the mixture through the intake. A stack of rotary disks 2.9 is arranged in the housing in a separation zone 13 which is located above an intake chamber defined by the housing adjacent to the intake, and in which the disks are spaced apart from each other with respect to the axis of the housing, and which serve to guide the flow of fluid upwardly through the housing to the discharge end, and also to assist in separation of the fluid into at least some of its separate component parts or phases.

Referring first to Figure 1, an apparatus according to the invention is designated generally by reference 10, and is intended to pump heavy oil bitumen upwardly from an underground stratum 2. The assembly 10 is shown in Figure 1b in enlarged view, and also located within a well casing pipe extending downwardly from a surface location and throughout ~~an overall depth shown by reference 3.~~the underground stratum 2. At the surface, there is provided electronic control equipment 1, connected by electric cable 7 to the apparatus 10. The apparatus 10 includes a separator/pump connected by bolts to the bottom of the tubing flange at the discharge head of the pump. The tubing flange is attached to tubing which extends down the well casing pipe, and with the tubing always being of smaller diameter than the casing.

Figure 1b illustrates a single pump 4 in the assembly ~~3,~~10, for ease of illustration, but in practical applications, more than one pump will be mounted in series below the highest pump at the bottom of the tubing.

A pump intake 5 allows the bituminous heavy oil fluid mixture to be admitted to the apparatus 10, and then to be pumped upwardly via a pump and housing assembly ~~3.~~4. Reference numerals ~~6~~8 and 9 designate electric motors to operate the apparatus.

The intake 5 is mounted below the lowest pump 4 and allows for the entry of fluid into the pump stack (in practice, the location of the pump intake is decided by geo-technical strata being drilled), and the pumps are located above the intake 5. Mounted below the intake 5 is a protective seal 6 which is intended to protect the one or more motors 8,9 mounted below, while still allowing for fluctuations in motor oil volume and also to accept the pump thrust, thereby isolating the motors 8,9 from this force. As indicated, the motor(s) ~~is~~8,9 are located below the protector 6. The motors are generally 60 Hz 3 phase squirrel cage motors running at 2500 to 3500 rpm. The bottom of the motors 8,9 may or may not have a base or sensing device, as required.

Above the ~~pump (s)~~pump or pumps 4 is the tubing which extends to the surface or well head. This tubing may incorporate various drains and valves situated to perform obvious functions relating to fluid transfer. The well head itself is intended to seal the top of the well from gas or fluid leaks, while allowing various lines to penetrate it.

Electrical energy is applied to the motors through a flat cable ~~(7)~~7 which is attached to the motor and runs along the side of the protector, the pump and other downhole equipment, and in between the tubing and the well casing. The cable runs through the well head and into a junction box intended to safely vent stray gases in the motor cable shell. Power is connected to the junction box from a switching or motor control cabinet ~~(1)~~1 and originates at a transformer that converts utility company voltage to that of the electrical system of the motor. Control and monitoring of motor speed and other characteristics are undertaken from the surface. Some monitoring of the pump performance also may be performed.

Figure 2 illustrates a dual pump stage and drive motor arrangement which may form a practical and preferred embodiment of the invention.

Figure 3 shows in detail one example of a turbo-disk pump/separator for use in an apparatus according to the invention, and which shows the internal pumping flow path for the high viscosity fluid through the interior of the housing of pump unit 4 shown schematically in Figure 1.

Referring to Figure 3, the pump/separator unit comprises three major separate components. First of all, the intake ~~2.~~12 comprises a circumferential slot formed in the wall of pump housing 2.15, and which communicates with an intake chamber 11 defined at a lower end of the casing 2.15, and which receives the incoming flow of viscous fluid mixture. A stack of five planar guide disks 12 is arranged in the intake, and which are vertically spaced apart to define flow passages therebetween. The disks 12 have no motion and are positioned about the general vertical axis of the housing of the apparatus, which is defined by motor drive shaft 2.0, driven via its lower end 2.18 by a motor spline connector 2.20, such as to permit fluid to flow into the intake 2.12 and to screen out particles larger than can be accommodated by the pump. The disks 12 measure 90 mm in diameter and are 2.5 mm in thickness, spaced vertically at 2 mm intervals.

~~A~~Having reference also to Figure 5a – 5c, a second major component of the pump/separator unit 4 comprises a central induction core 2.11, 30 which is formed by seven spiral slots 31 which can be set at a variety of angles from the vertical, arranged about a hollow 20 mm drive core 32 machined to match the motor output shaft 2.0. This is shown by reference 2.11 in Figure 3, and which effectively forms an inner impeller rotatably mounted in the housing and which is operable to generate a spirally upwardly moving column of fluid which rotates around the axis of the housing, and thereby induces inward flow of the fluid mixture through the intake 12.

A keyway 2.1 is provided to lock the drive core 2.16 onto the power input shaft 2.0 of the electric motor. The induction core is situated about the hollow drive core and forms the central section, to which the five disks 12 of the intake are attached, for rotation therewith.

The spiral slots 2.11 cut into the central induction core are angled in such a way that, the greater the viscosity of the fluid to be pumped, the flatter will be the angle which is formed. Thus, compression separators can be constructed to incorporate a variety of spiral slots. By way of example only, in tests with a bitumen heavy oil of viscosity two hundred thousand times that of water, slot angles of about 60 degrees measured against the vertical were found to be suitable.

In ~~a~~one or more separation zones 13, 14 within the pump housing 2.15, and above the intake chamber 11, there are arranged stacks of rotary disks 2.9 about the spiral slots 2.11 forming a rotor 19, and a diffuser arrangement comprising diffuser hub 2.5, diffuser vane 2.6 and diffuser plate 2.7 separate the zones 13 and 14, and similar a diffuser arrangement separates zone 13 from the intake chamber 11. The diffuser arrangement 2.5,2.6,2.7 is shown in greater detail in ~~Figure 6.~~Figures 6a and 6b.

By way of explanation, the head loss at an abrupt enlargement or at the exit of a pipe can be considerably reduced by the substitution of a gradual, tapered enlargement, usually called a diffuser or a cooperator, the function of which is to gradually reduce the velocity of the fluid and thus eliminate, as far as is practicable, the eddies responsible for energy dissipation. According to Bernouilli's equation, in a perfect diffuser there would be an increase in pressure in the direction of flow if steady flow and uniform conditions over the inlet and outlet cross-sections are assumed. The actual pressure rise is less than the perfect model assumed because of head loss, and the loss of head which does occur in the diffuser is dependent an inlet conditions, the angle of divergence, degree of pipe friction present and the eddies formed in the flow.

As can be seen more clearly in Figure 4, the bottom horizontal ~~plate~~disk 2.9 of the rotor ~~2.9~~19 is only open in the centre thereof, in the vicinity of the rotor spiral 2.11. This is the only inlet into the rotor 19 from the intake or diffuser immediately below the stage of the pump, and enables fluid to be brought up the central rotor spiral 2.11 to the top horizontal ~~plate~~disk 2.9 and to fill the spiral core. There is no outlet at the top horizontal ~~plate~~disk 2.9 in the vicinity of the rotor spiral 2.11, as a result of which fluid is forced to exit radially outwardly through the spaces between the ~~plates~~disks 2.9 as shown in greater detail in Figure ~~6,,~~4 and 5c and out the diffuser, although the diffuser arrangement shown in ~~Figure 6~~Figures 6a,6b 5a-- ~~is~~ are upside down relative to that shown in Figures 3 and 4. Each diffuser arrangement comprises a diffuser hub 2.5 and diffuser vane 2.6, the function of which is to cause fluid leaving the rotor 19 with radial and circumferential movement only to be directed upwards and back into the centre of the rotor spiral 2.11 of the pump stage immediately above as smoothly as possible, to enable each stage to act cumulatively. The diffuser hub 2.5 allows fluid to enter from the outside of the diffuser, and then the spiral arms of diffuser vane 2.6 turn the flow direction so as to spiral inwards more than upwards.

To operate the pump, power is fed to the motor to cause rotation of motor shaft 2.0, to build up speed quickly to rotation at approximately 3500 rpm. The rotating motor shaft is common to the pump/separator shaft which is mounted above the motor, the intake and the protector. Therefore, rotation of the motor is transferred to the pump/shaft and causes the separator/pump to rotate as well.

The separator/pump uses the principles exhibited by a common meteorological tornado to develop a spirally upwardly moving force which draws the heavy oil bituminous fluid upwardly, and this is a more efficient means of fluid transfer, rather than relying upon impact between the fluid components and a lifting surface (as in conventional lifting impeller pump arrangements) to impart upward movement. The lessening of particle impacts, gives greater control over the substance heating and friction and factors, which reduces motor horse power requirements.

The separator/pumping incorporates flat or concave disks attached to the rotary shaft as described above. The heavy oil bitumen is introduced through the intake mounted directly below the lowest pump at the centre of the rotating rotary where the boundary layer drag/viscosity drag an either side of the disk imparts energy to the pumped material and the fluid moves outward in a helical path to a suitable configured discharge opening and into a diffuser where the kinetic energy of the fluid is exchanged for static pressure.

The size, number, spacing and speed of the disks will vary according to the characteristics of the heavy bitumen being pumped and the desired performance. Since there is little relative motion between the fluid lift vortex boundary layer and the surface of the disk, there is little erosion or abrasion of the impeller disk, even when pumping the most abrasive of slurries. Further, with substantially no cavitation, the pump separator can effectively be used to pump and separate gases, liquids or solids, or any combination of the two or three phases.

This versatility allows the separator/pump to move fluid and separate materials or combinations of materials not normally associated with pumping and later separating.

The viscous fluid mixture which is to be handled undergoes a separation process, while the pumping operation is being carried out. The particles of the fluid have different specific gravities, depending on whether they tend towards solid, liquid or gaseous states. As the separator/pump is rotated at high speeds, the frictional drag forces that are part of the pumping process also convey energy in the form of heat to the heavy oil bitumens. This heat improves the viscosity of the bitumen to a point where it will readily flow and be capable of being pumped. The centrifugal and centripedal forces imparted to the bitumen during the fluid inter phase with the separator/pump causes heavier particles to move towards the outside of the pump housing faster than those particles of lesser specific gravity, such as liquids and gases. This process eventually separates the fluids into distinct cross-sections, with heavier particles furthest away from the centre and lighter fluids closer to the centre, as in a conventional centrifuge.

Accordingly, the pumping surfaces of the apparatus impart energy by the principle of "boundary layer drag", and separation occurs by mass mixing and subsequent centrifugal separation as an integral part of the lifting process.

Figure 4 is an illustration, similar to Figure 3, and showing the spirally upwardly moving flow of fluid through the interior of the apparatus.

When the rotor 19 is spinning, the forces originating from the drag an the fluid at the boundary layer of the spinning horizontal ~~plates~~disks 2.9 impart radial and circumferential fluid movement, which in turn begins to evacuate fluid from the rotor spiral again. This motion is continuous if the angle of the individual spirals of the rotor spiral 2.11 is not too steep in relation to the viscosity of the fluid, and it therefore follows that a shallower angle of the spirals in the rotor spiral 2.11 is necessary to accommodate thicker fluids, as discussed above.

Since the fluid leaves the rotor with radial and circumferential movement only, this fluid motion must be directed upwards and back into the centre of the rotor spiral 2.11 of the pump stage immediately above. In order for the successive pump stages to act cumulatively, this must be carried out as smoothly as possible, and this is the function of the diffuser arrangements installed between each stage, as discussed above. In particular, as the fluid flow is to be directed back into the centre of the pump stage immediately above, the diffuser hub 2.5 allows fluid to enter from the outside of the diffuser, and then the spiral arms of the diffuser vane 2.6 turn the flow direction inwards. The fluid already has a spiral flow tendency imparted by the rotor horizontal ~~plate~~disks 2.9 of the pump stage below, and this spiral flow tendency is increased as the fluid enters through the diffuser vanes and into the next pump stage above.

During operation of the pump/separator unit, the bottom stages of the pump are immersed in fluid, and fluid flow towards the first stage is initiated by the net positive suction head of the fluid around the outside of the pump and the intake ~~screen 2.~~12. The amount of fluid pressure required above the intake 12 on the outside of the pump is a function of viscosity and net flow, and the spiral nature of the fluid flow is not necessary at the intake 12 as the rotor of the first pump stage will initiate~~d~~ it.

Although a diffuser arrangement is shown between the intake 12 and the first pump stage, such a diffuser is not necessary, since, as in a vortex, the fluid takes an progressively more of a spiral nature as it approaches the first rotor spiral 2.11, but the fluid flow some distance away may be linear and not yet spiral.

The rotor spiral 2.11 distributes fluid to the spaces between horizontal ~~plates~~disks 2.9, and by varying the angle of the spiral 2.11, a variety of viscosities of fluids can be handled. Furthermore, the spiral 2.11 distributes the thicker fluids more evenly towards horizontal ~~plate~~disk spaces with the result that all horizontal ~~plates~~disks 2.9 add movement to the fluid and help initiate spiral fluid movement. Since centrifugal forces act on heavier particles more than lighter particles, heavier particles such as sand will move to the outside of the body more quickly and remain there, whereas light oils and water will not be thrown outwards so quickly, and gas bubbles should stay fairly central to the flow. Assuming laminar flow through the diffusers and impellers, little or not re-mixing will occur, and a fluid column will stay separated as it passes through the pump/separator unit.

Although two pump stages are shown in the arrangement of Figures 3 and 4, a single pump stage could be used as a common centrifuge to separate fluids. Alternatively, several stages could be used, the top stages being left without diffusers to avoid any re-mixing which may occur after each pass through the diffuser and into the next rotor.

Figure 5 illustrates an alternative arrangement of components of a pump/separator unit for use in an apparatus according to the invention, and Figure 6 is a schematic illustration of the induced flow paths of the high viscosity fluid as it undergoes pumping and separation treatment by the apparatus according to the invention.

~~invention.~~

Improvements Over Existing ~~Technology~~

Technology - Advantages over existing technology

Separation of the Heavy Oil Bitumen

Heavy oil bitumen can contain varying degrees of gases, liquids and solids. All of these constituent parts react differently to the pumping process due to the varying centrifugal force acting an them, as they have a tendency to migrate to different radial parts of the flow cross-section. As this can be performed as part of the pumping process (in apparatus according to the invention) without the usual degradation of impeller performance, the process of pumping and separating can be performed concurrently.

The impeller of a traditional pump is keylocked onto the shaft that runs from the motor through the centre of the pump, but is free-floating up and down on that shaft. If the traditional pump should experience a bubble of gas running through it, the impeller will go into a condition known as "upthrust". Upthrust refers to a condition when the motor rpm increases dramatically due to the large and sudden reduction in the density (and thus resistance) of the fluid being pumped. When the pump goes into this condition, the impellers push up against the seals at the top of the pump causing premature wear and resistance. In addition, if the gas bubbles are large enough to cause the pump to cavitate (e.g. an air lock stops the flow of fluid) the motor is in danger of damage as well because the ~~rmp~~rpm may increase briefly beyond safe limits, as well as the motor may be deprived of the cooling offered by the regular flow of fluid.

This potential danger predicates most traditional installation to also install an additional piece of equipment referred to as a "gas separator" which forces the gas to be pumped to the surface in the gap between the well casing and the pressurized well tubing. However, a gas separator is not necessary as additional equipment on the heavy oil bitumen separator/pump according to the invention.

Abrasives

Most heavy oil bitumen deposits are located in sandstones and other porous ground strata which "shed" into the oil as it is being gathered. Such abrasives can represent up to 50 percent of the total volume being pumped. Since a typical known impeller type pump uses the lifting surface an the impeller to push the pumped materials up the tubing, the contact between the abrasive and the impeller face results in premature wear of the impeller face and seals and the associated reduced performance. The additional strain an both the pump and the 'motor to maintain flows can reduce their lives to as little as there months or less in extreme cases making the more abrasive fluid uneconomical to recover.

The separator/pump according to the Invention uses the principles exhibited by a common meteorological tornado to develop a force which causes a vacuum-type pressure to pull the heavy oil bitumen fluid rather than grab and push it. The result is a more efficient pump that does not rely on the impact between fluid particles and a lifting surface to impart movement. The lessening of the particle impacts gives greater control over the substance heating and friction which reduces motor horsepower requirements.

Finally, while there has been described use of a pump/separator apparatus according to the Invention to pump high viscosity fluids such as heavy oil bitumen mixtures, it should be understood that the apparatus may be used to handle and to lift other fluid/liquid/solid dispersion mixtures, in which the liquid content may be oil, water or slurry. The apparatus may be ~~uses,~~ used, for example, to pump silt from estuaries, in harbours, or in a pumping installation for pumping raw sewage.

THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. A pump/separator apparatus for pumping a viscous fluid mixture upwardly from an underground location and for carrying out at least partial separation of the mixture into separate component parts or phases during the pumping operation, said apparatus comprising:

a substantially cylindrical housing having an intake at or near its lower end to receive the viscous fluid mixture, and an upper discharge end;

an inner impeller rotatably mounted in the housing, said impeller having a radial extent which is less than the radial extent of an internal chamber defined by the housing, and said impeller being rotatable around an axis of the housing in order to generate a spirally upwardly moving column of fluid which thereby induces inward flow of the fluid mixture through the intake; and

a stack of rotary disks arranged in the housing in a separation zone located above an intake chamber defined in the housing adjacent to the intake, said disks being spaced apart from each other with respect to the axis of the housing, and serving to assist in separation of the fluid into at least some of its separate component parts or phases.

2. An apparatus according to claim 1, wherein the intake comprises a circumferential inlet formed in the wall of the housing.

3. An apparatus according to claim 2, wherein a stack of inlet vanes is mounted in an exterior wall of the housing.

4. An apparatus according to claim 3, wherein the inlet vanes comprise a set of generally planar and parallel vanes which are spaced apart from each other with respect to the axis of the housing.

5. An apparatus according to claim 1, wherein the impeller comprises a plurality of generally spirally extending passages arranged radially inwardly of the stack of rotary disks and serving to direct fluid flow between said disks.

6. An apparatus according to claim 1, further comprises diffuser means arranged downstream of the impeller and serving to direct fluid flow exiting said impeller radially inwardly and upwardly.

7. An apparatus according to claim 6, wherein said diffuser means comprises inlet means, an outlet arranged radially inwardly of said inlet means, and a plurality of generally spirally extending arms for directing fluid from said inlet means to said outlet.

8. An apparatus according to claim 7, wherein a diffuser is arranged in the housing to separate the intake chamber from the separation zone.

9. An apparatus according to claim 8, wherein the separation zone is sub-divided by a further diffuser, and with a respective stack of rotary disks in each sub-divided portion.

10. An apparatus according to claim 1 and comprising a multi-component assembly, including more than one pump, each having its own respective electrical drive motor coupled therewith.

11. A pump impeller having a rotational axis, an upstream end, and a downstream end comprising:

a plurality of parallel flow passages spiraling axially about the rotational axis, the axial flow passages being open at the upstream end and blocked at the downstream end; and

a stack of circular disks, each disk extending radially and concentrically from the axial flow passages and being spaced axially from each other disk for forming a plurality of radial flow passages which communicate with the axial flow passages so that fluid flows from the impeller's open upstream end, through the axial flow passages and into the radial flow passages wherein fluid issues from the radial flow passages between disks.

12. An improved pump for pumping viscous fluids implementing comprising:

an impeller having a rotational axis, an upstream end, a downstream end and a plurality of parallel flow passages spiraling axially about the rotational axis, axial flow passages being open at the upstream end and blocked at the downstream end;

a stack of circular disks, each disk extending radially and concentrically from the axial flow passages and being spaced axially from each other disk for forming a plurality of radial flow passages which communicate with the axial flow passages so that fluid flows from the impeller's open upstream end, through the axial flow passages and into the radial flow passages wherein the fluid issues from the radial flow passages; and

a housing in which the impeller is concentrically and rotationally supported, an annular flow passage being formed between a radial extent of the impeller and the housing for receiving and conducting the flow of fluid incrementally issuing from the radial flow passages.

13. The improved pump as recited in claim 12 further comprising

a plurality of improved impellers, provided in a co-axial arrangement of successive pumping stages; and

a plurality of stationary vane diffusers, one positioned between each stage.

14. The improved pump as recited in claim 6 wherein each diffuser has peripheral inlet located adjacent the outer circumference of the furthermost downstream disk of an impeller of an upstream stage and an outlet located adjacent the axial flow passages of the impeller of the next successive downstream stage.

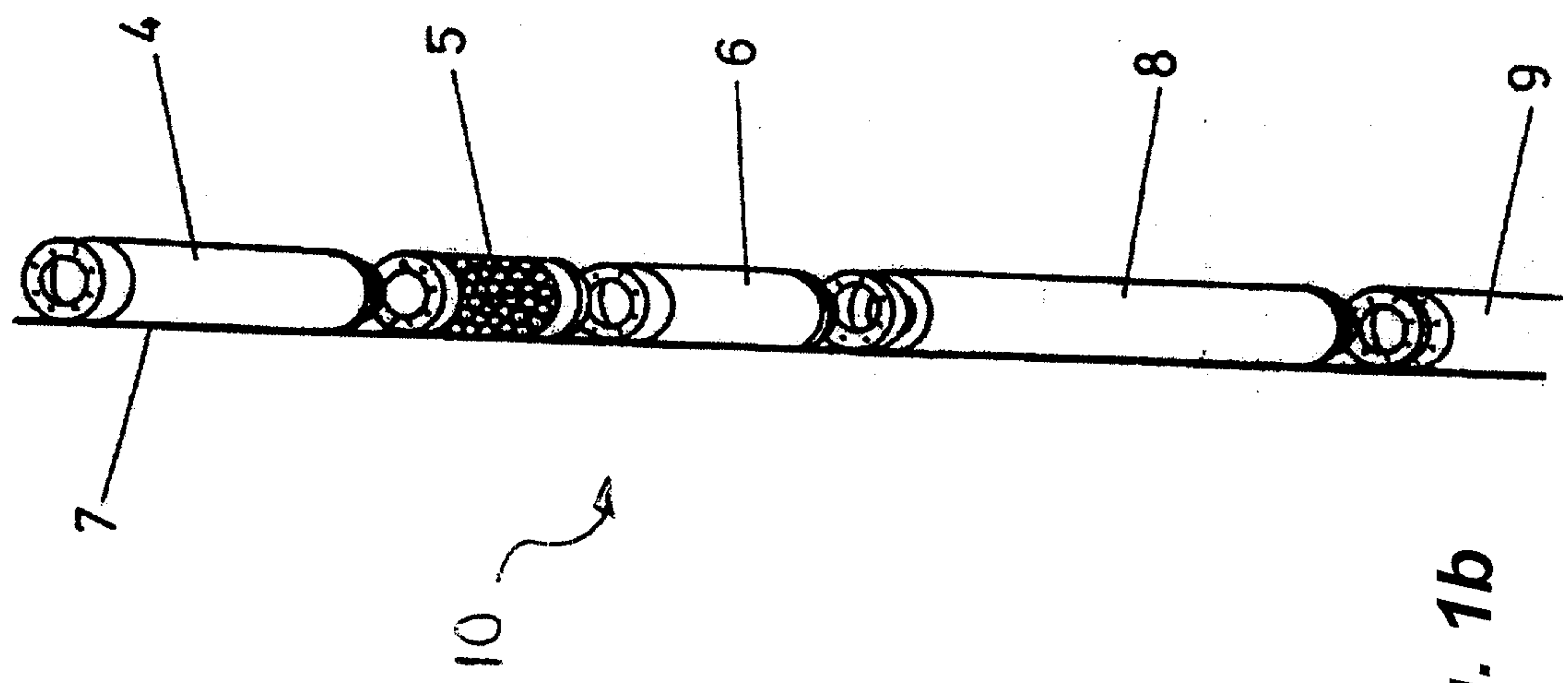


Fig. 1b

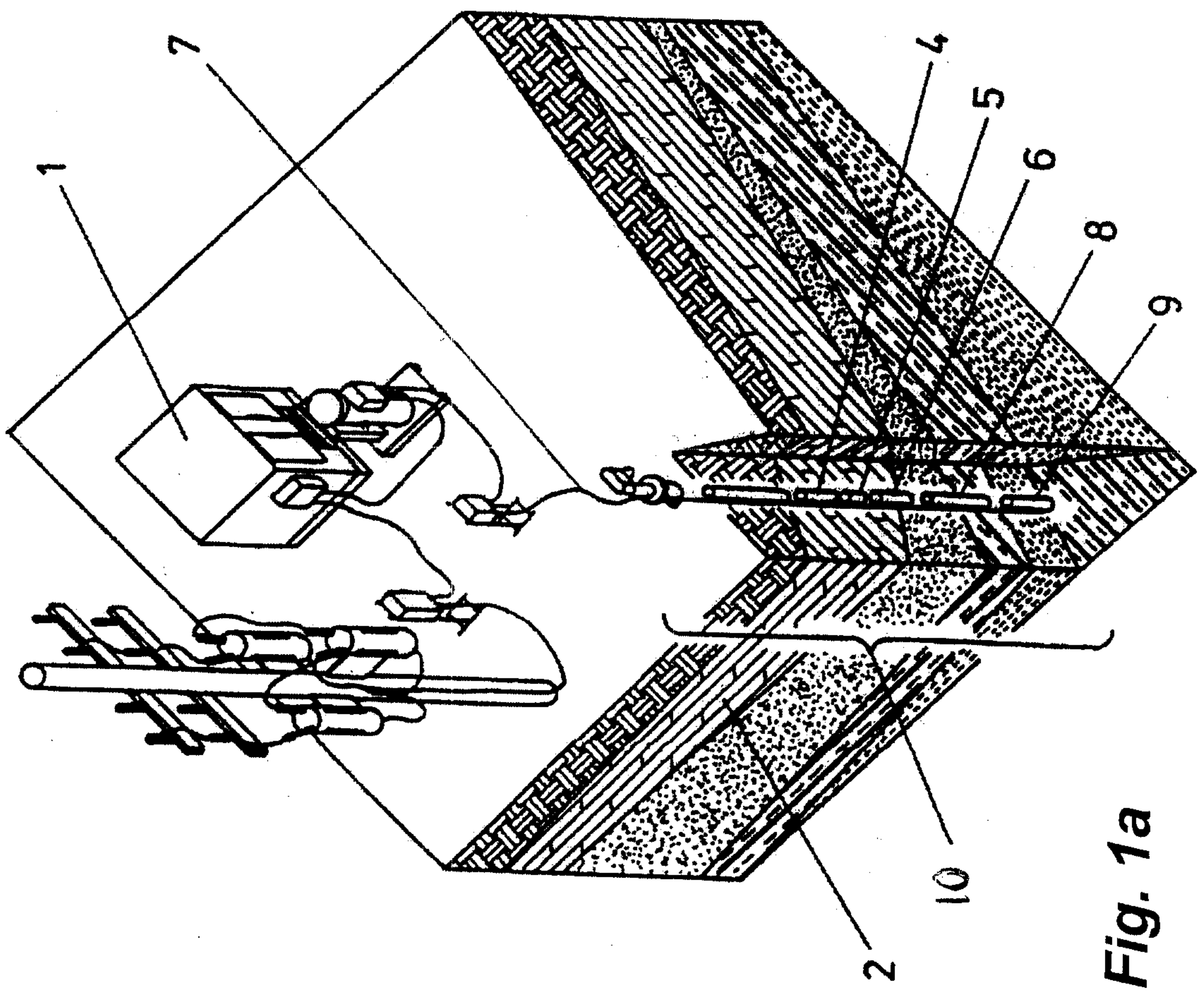


Fig. 1a

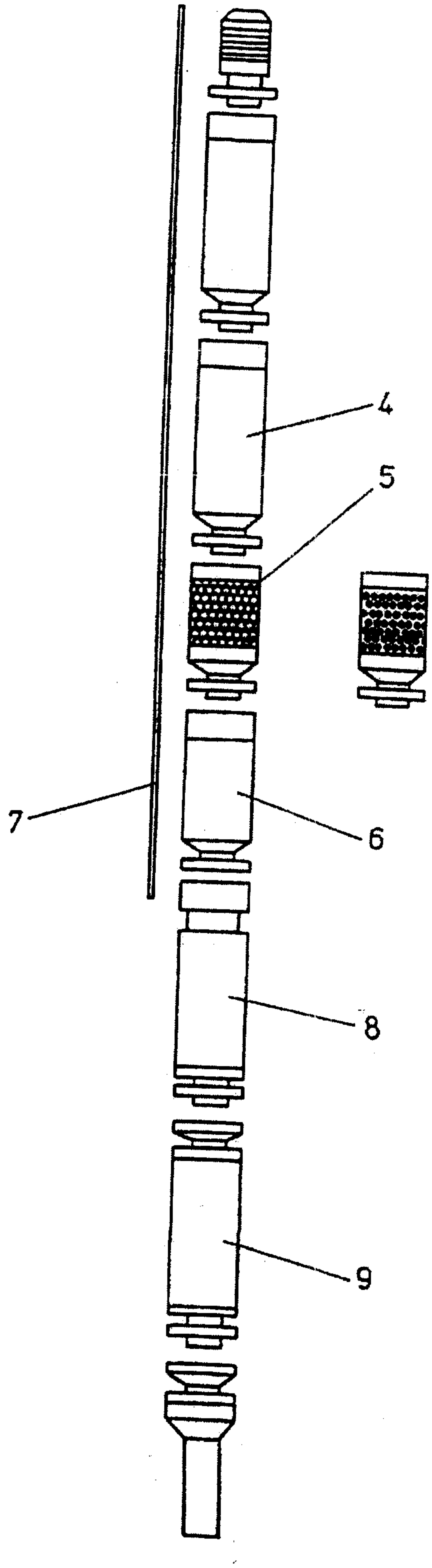


Fig. 2

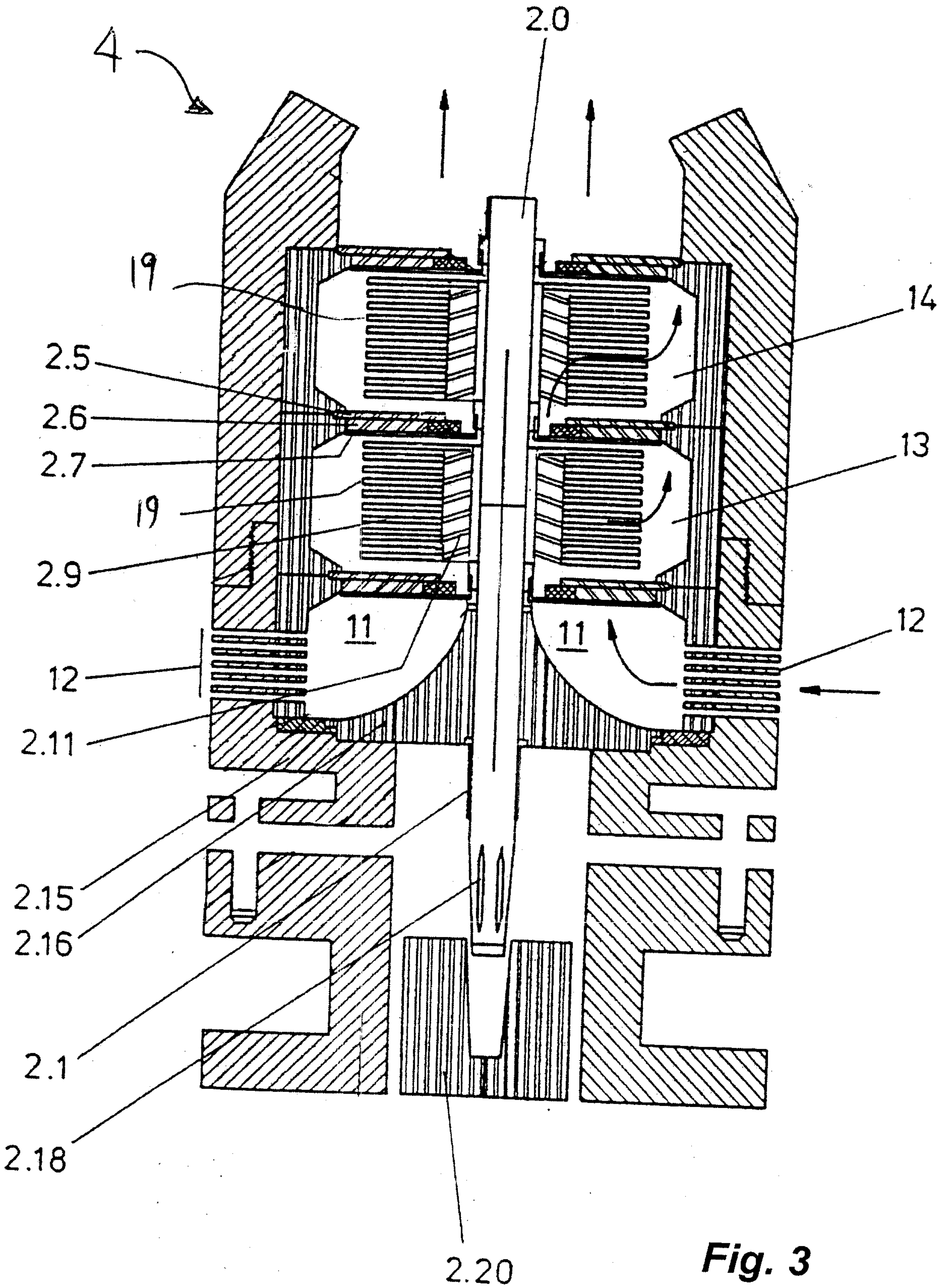


Fig. 3

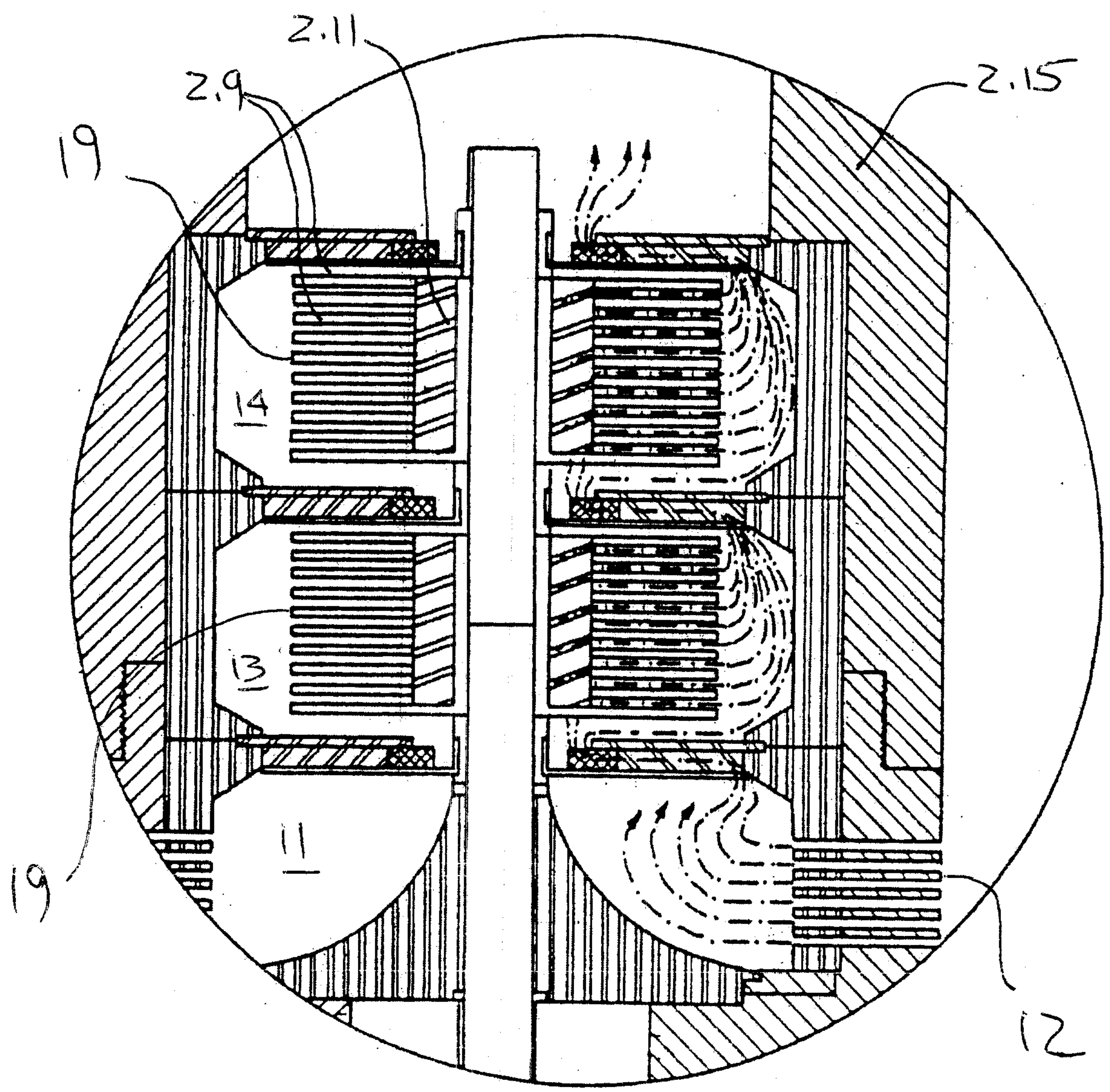


Fig. 4

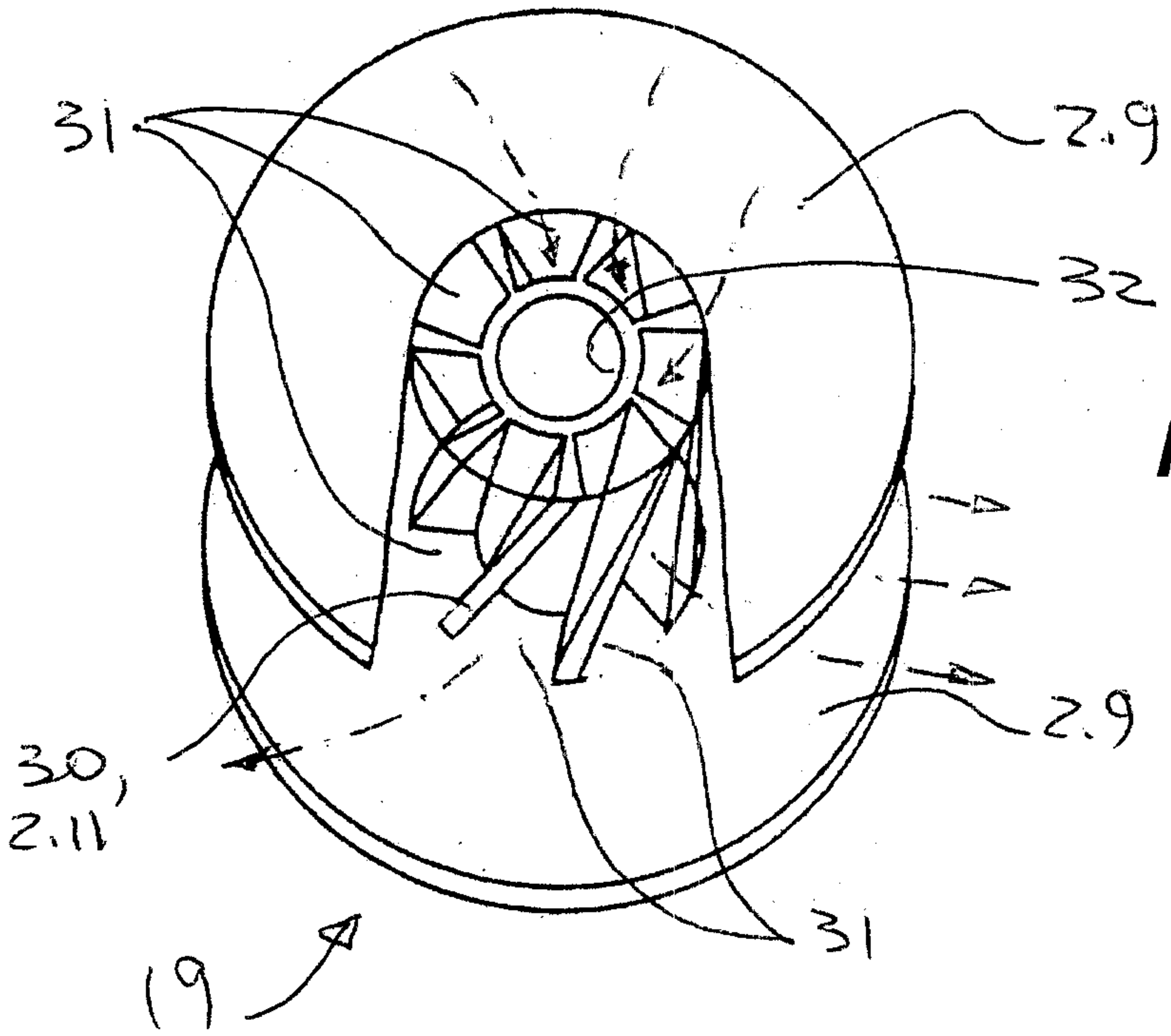


Fig. 5a

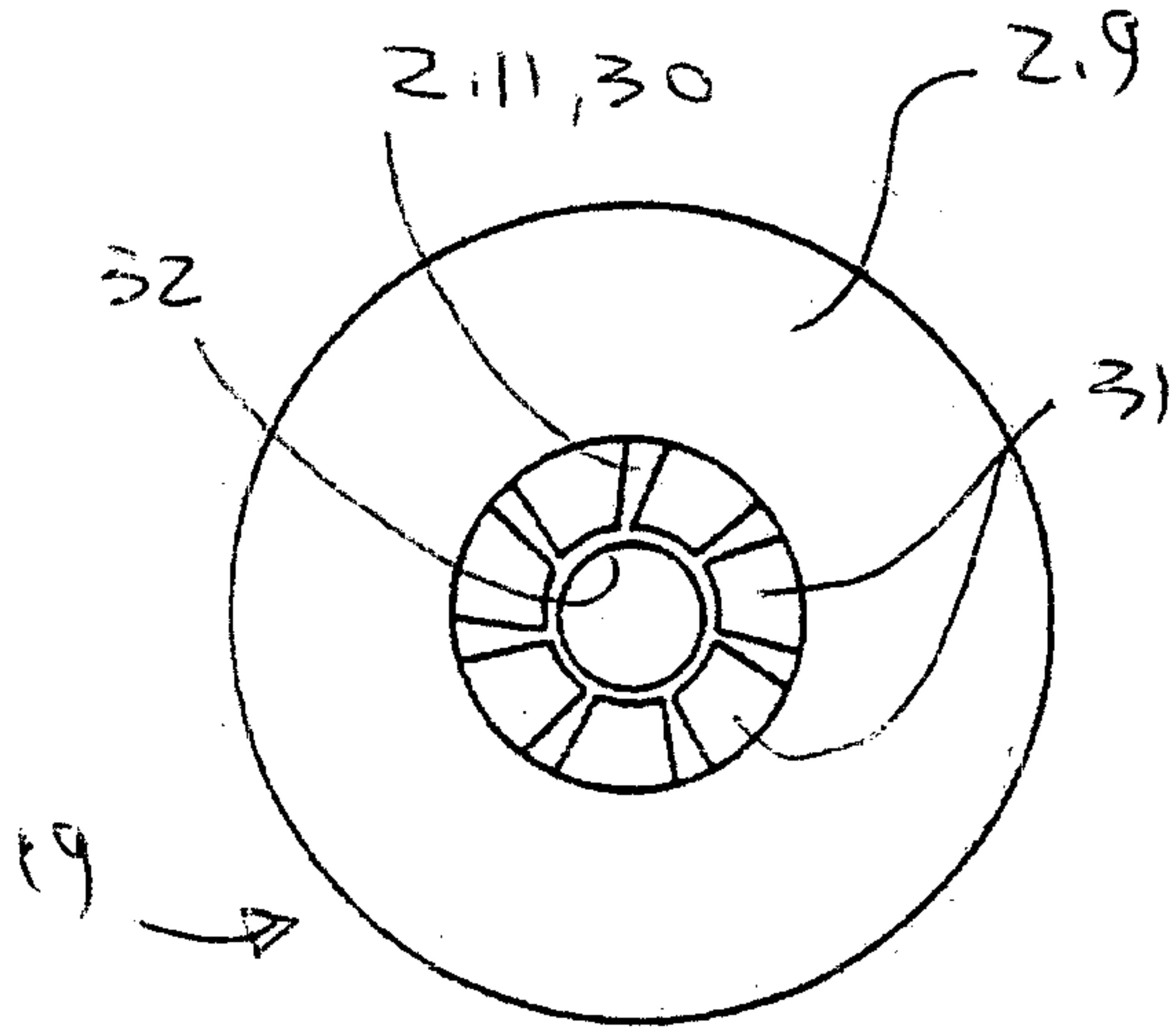


Fig. 5b

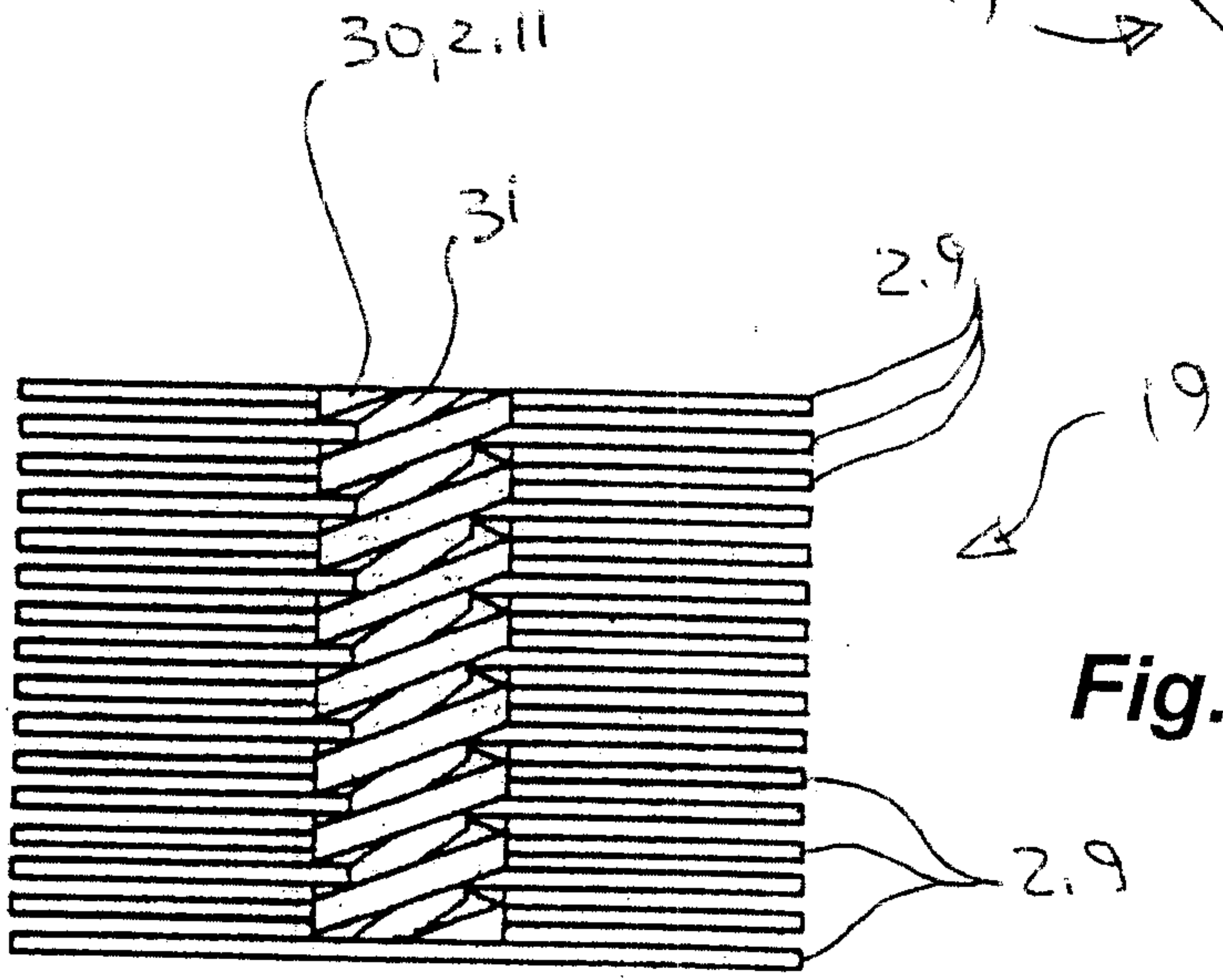


Fig. 5c

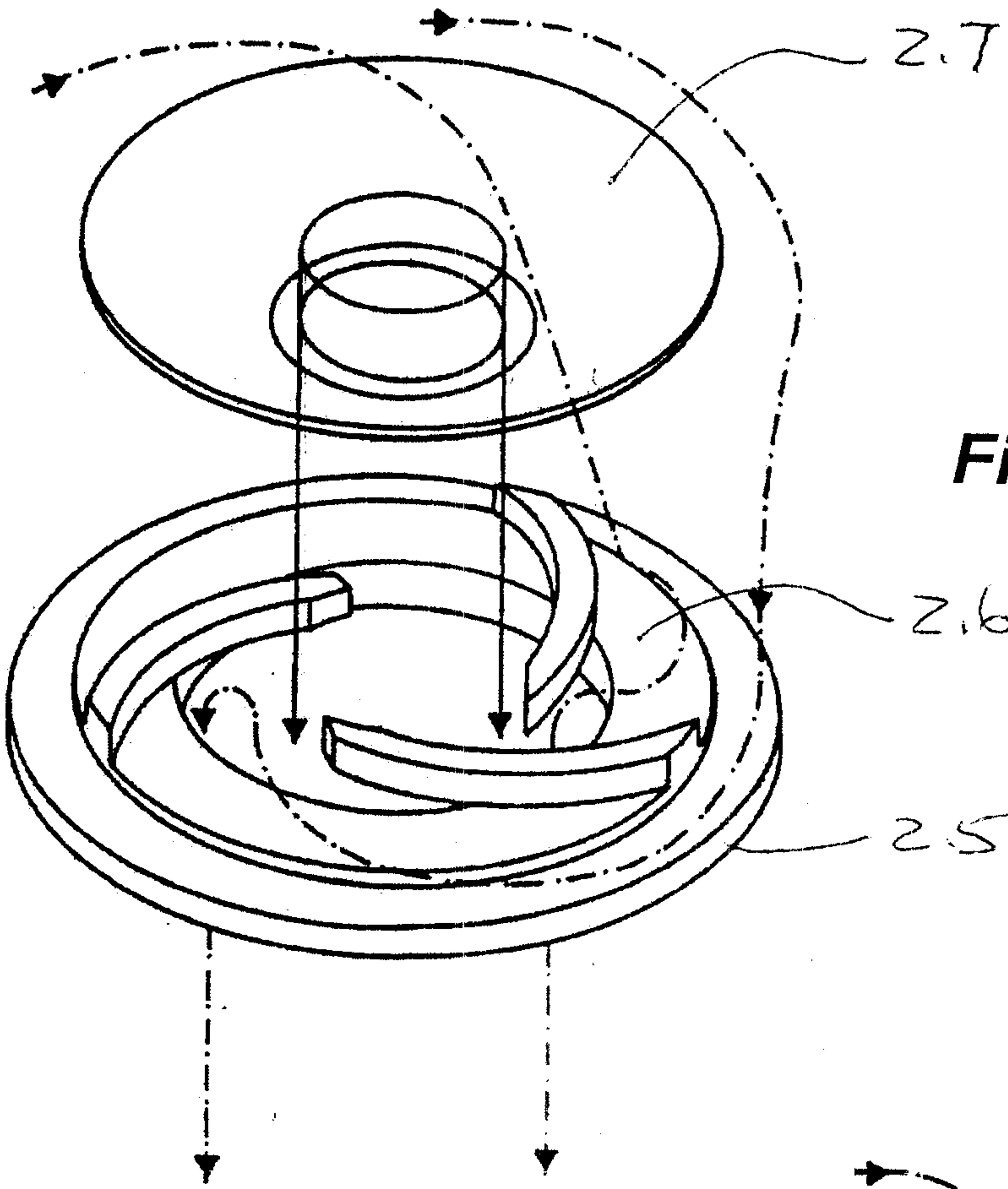


Fig. 6a

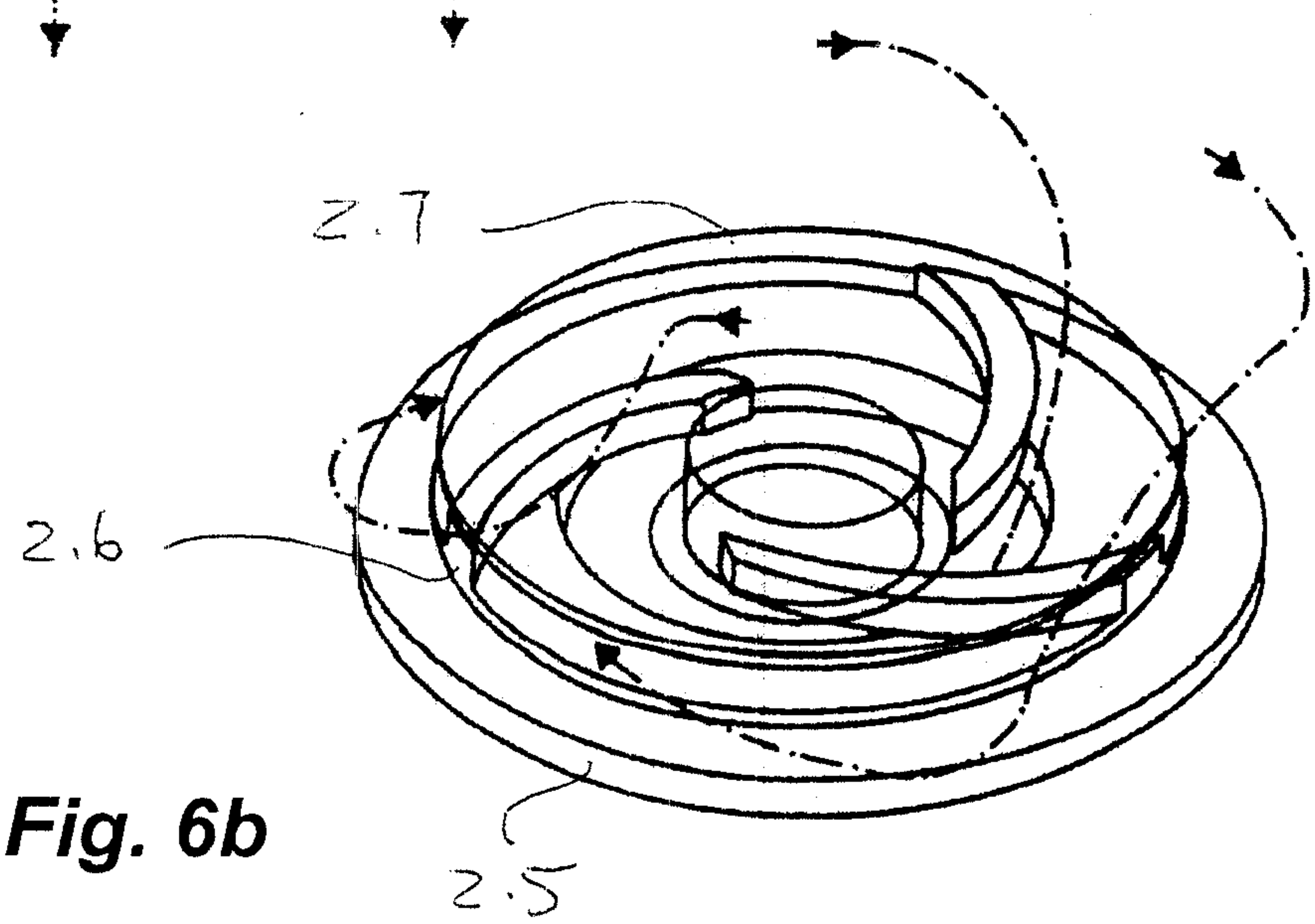
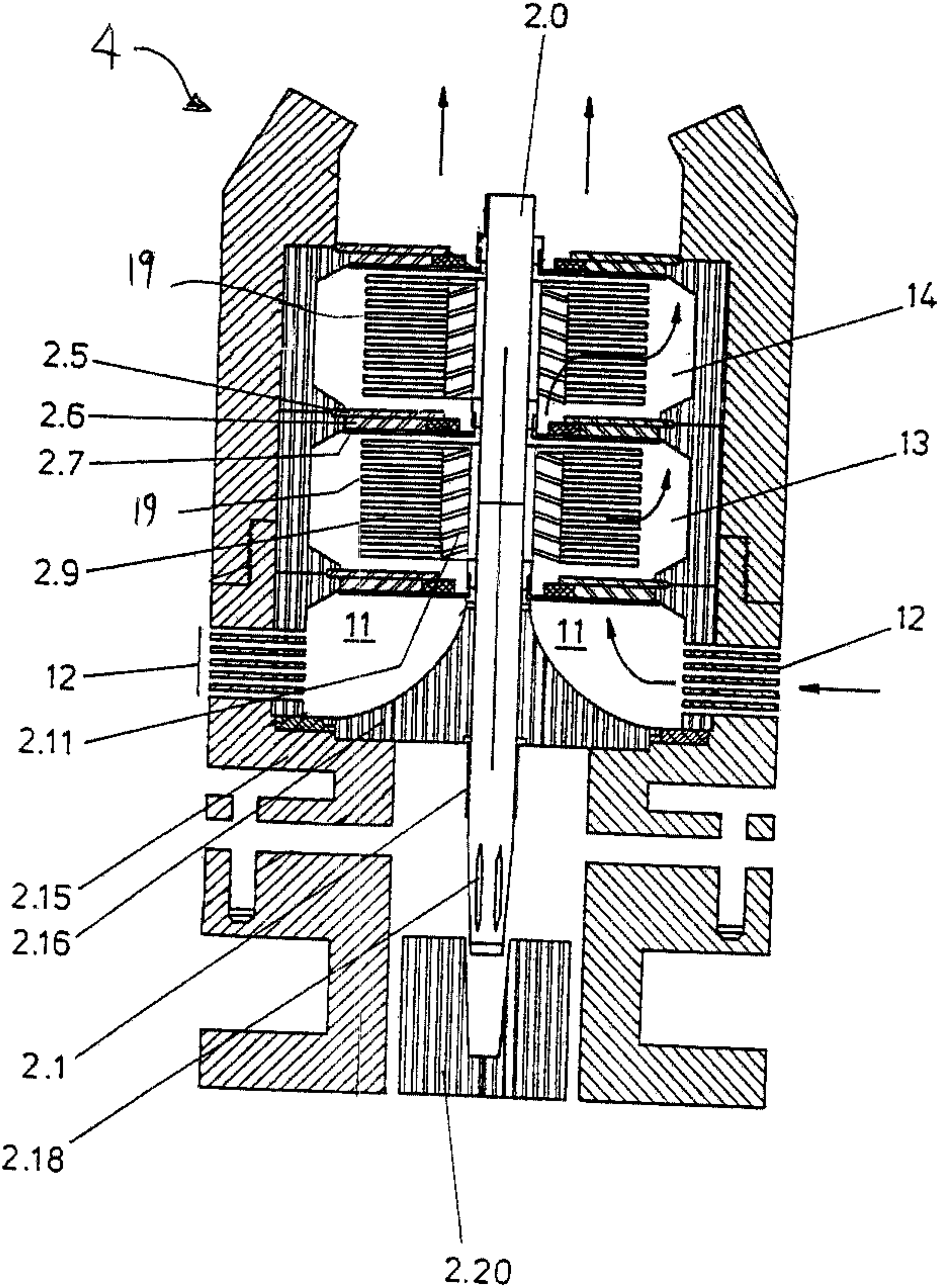


Fig. 6b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