

(12) PATENT
(19) AUSTRALIAN PATENT OFFICE

(11) Application No. AU 200045534 B2
(10) Patent No. 757839

(54) Title
Device for delivering single-phase or multiphase fluids without altering the properties thereof

(51)⁶ International Patent Classification(s)
H02K 007/09 F16C 039/06
A61M 001/10 H02K 007/14

(21) Application No: 200045534 (22) Application Date: 2000 . 04 . 19

(87) WIPO No: WO00/64030

(30) Priority Data

(31) Number	(32) Date	(33) Country
19918841	1999 . 04 . 20	DE
19944863	1999 . 09 . 18	DE

(43) Publication Date : 2000 . 11 . 02
(43) Publication Journal Date : 2001 . 01 . 04
(44) Accepted Journal Date : 2003 . 03 . 06

(71) Applicant(s)
Berlin Heart AG

(72) Inventor(s)
Peter Nusser; Johannes Muller; Hans-Erhard Peters

(74) Agent/Attorney
PIZZEYS,GPO Box 1374, BRISBANE QLD 4001

(56) Related Art
WO 98/28543
WO 97/49440

PCT
 WELTORGANISATION FÜR GEISTIGES EIGENTUM
 Internationales Büro
**INTERNATIONALE ANMELDUNG VERÖFFENTLICHT NACH DEM VERTRAG ÜBER DIE
 INTERNATIONALE ZUSAMMENARBEIT AUF DEM GEBIET DES PATENTWESENS (PCT)**



<p>(51) Internationale Patentklassifikation ⁷ : H02K 7/09, 7/14, A61M 1/10, F16C 39/06</p> <p style="text-align: right;">A1</p>	<p>(11) Internationale Veröffentlichungsnummer: WO 00/64030</p> <p>(43) Internationales Veröffentlichungsdatum: 26. Oktober 2000 (26.10.00)</p>
<p>(21) Internationales Aktenzeichen: PCT/EP00/03563</p> <p>(22) Internationales Anmeldedatum: 19. April 2000 (19.04.00)</p> <p>(30) Prioritätsdaten: 199 18 841.6 20. April 1999 (20.04.99) DE 199 44 863.9 18. September 1999 (18.09.99) DE</p> <p style="text-align: center;">BERLIN HEART AG</p> <p>(71) Anmelder (für alle Bestimmungsstaaten ausser US): MEDI-PORT-KARDIOTECHNIK GMBH [DE/DE]; Wiesenweg 10, D-12247 Berlin (DE).</p> <p>(72) Erfinder; und (75) Erfinder/Anmelder (nur für US): NÜSSER, Peter [DE/DE]; Wustrower Str. 23, D-13051 Berlin (DE). MÜLLER, Johannes [DE/DE]; Güntzelstr. 63, D-10717 Berlin (DE). PETERS, Hans-Erhard [DE/DE]; Lychener Str. 33, D-10437 Berlin (DE).</p> <p>(74) Anwälte: GULDE, Klaus, W. usw.; Gulde Hengelhaupt Ziebig, Schützenstrasse 15-17, D-10117 Berlin (DE).</p>	<p>(81) Bestimmungsstaaten: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW, ARIPO Patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), eurasisches Patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), europäisches Patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI Patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).</p> <p>Veröffentlicht <i>Mit internationalem Recherchenbericht. Vor Ablauf der für Änderungen der Ansprüche zugelassenen Frist; Veröffentlichung wird wiederholt falls Änderungen eintreffen.</i></p>

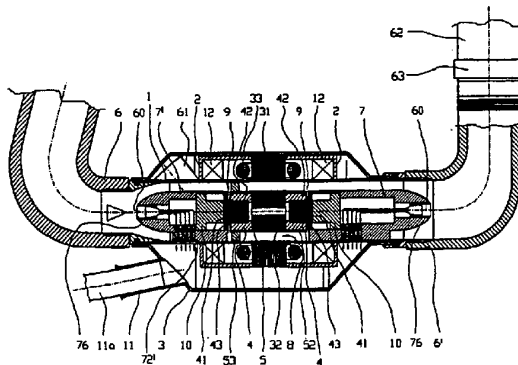


(54) Title: **DEVICE FOR DELIVERING SINGLE-PHASE OR MULTIPHASE FLUIDS WITHOUT ALTERING THE PROPERTIES THEREOF**

(54) Bezeichnung: **VORRICHTUNG ZUR SCHONENDEN FÖRDERUNG VON EIN- ODER MEHRPHASIGEN FLUIDEN**

(57) Abstract

The invention relates to a device for delivering single-phase or multiphase fluids without altering the properties thereof. The aim of the invention is to provide a device for carefully delivering single-phase and multiphase fluids which, consisting of a simple construction, does not alter or only insignificantly alters the properties of the fluid to be delivered and, in particular, minimizes dead water zones and turbulences of the fluid to be delivered. The invention provides a device for delivering single-phase or multiphase fluids which is comprised of a tubular cavity (1) that guides the fluid, whereby the rotor (32) of the electric motor is configured as a rotatable delivering part (5) mounted with axial alignment inside the tubular cavity (1). The inventive device also comprises at least one fluid guiding device (7, 7') arranged in front of and/or behind the delivering part (5) and is characterized in that the rotatable delivering part (5) is contactlessly mounted by means of a magnetic bearing.



Abstract

The invention relates to a device for the gentle delivery of single- or multiphase fluids.

The invention is based on the object, to provide a device for the gentle delivery of single- or multiphase fluids, which with a simple structural design does not or only insignificantly change the to be delivered fluid in its characteristics and especially minimises wake areas and vortexing of the to be delivered fluids.

The invention consists of a device for the gentle delivery of single- or multiphase fluids, consisting of a tubular hollow tubular body (1), carrying the fluid, wherein the motor rotor (32) of the electric motor formed and supported inside the tubular hollow body (1) is axially positioned rotatable delivery element (5) and is having at least one fluid guide unit (7, 7'), which is arranged in front of and/or behind the delivery element (5), characterised in that the rotatably drivable delivery element (5) is supported contact free by means of a magnetic bearing.

(Fig. 1)



**Device for delivering single-phase or multiphase fluids
without altering the properties thereof**

Description

The invention relates to a device for delivering single-phase or multiphase fluids without altering the properties thereof according to the preamble of claim 1.

Especially less stable multiphase fluids, for example emulsions and dispersions, which can experience irreversible changes by an energy insertion, can disadvantageously get during the delivery in corresponding devices, like pumps, into instable areas.

A very sensitive fluid system is blood. This opaque red body liquid of vertebrate animals circulates in a closed vascular system, wherein the rhythmical contraction of the heart presses the blood into the different areas of the organism. In this case the blood transports the respiratory gases, which are oxygen and carbon dioxide, as well as nutrients, metabolic products and body own substances. In this case, the blood vascular system including the heart is hermetically sealed from the environment, so that the blood experiences no changes in the healthy organism, when it is pumped via the heart through the body.

It is known, that the blood tends, when contacting with materials foreign to the body or through foreign energy affect, to a haemolysis and a thrombi formation. The formation of thrombi can be deadly for the organism, as they lead to a clogging up in the far branched vascular system. Haemolysis describes the condition, that the red blood cells are lysed –destroyed- further than the physiological degree. The causes for the haemolysis could be mechanical or metabolic. Increased haemolysis causes multiple organ damage and can lead to the death of the human being.



On the other hand it has been shown, that it is principally possible to support the pump capacity of the heart under specific constructive conditions or even to replace the natural heart by an artificial heart, but a constant operation of implanted heart support pumps or artificial hearts is at the moment only limitedly possible, as the interaction of these artificial products with the blood still lead to disadvantageous changes of the blood.

In the known State of the Art different development directions of blood pumps are distinguishable. Heart support pumps and artificial hearts can be designed starting from the required pressure difference and the volume flow, as well as the displacement principal as a so-called pulsating pump or according to the turbo principle as a radial or axial flow device. At the moment these three named designs are developed in parallel. The flow devices show because of the high capacity density of this type of devices smaller dimensions than piston devices. Within the group of pumps, which function according to the turbo principal, the axial pump variant is as a rule smaller than the radial variant. A turbo device can be designed generally for the given pressure difference and the given volume flow very differently, for example as an axial or a radial pump with greatly different rotational speeds.

The axial blood pumps known from the State of the Art, comprise generally an outer cylindrical pipe, in which a delivery element rotates, which is formed as a rotor of a motor stator arranged outside and which, therefore, transports the blood in an axial direction. The support of the delivery element is a problem. A purely mechanical support is disadvantageous because of the damage of the blood and even because of the relatively high friction values. Also the up-to-now described magnet bearing types have not lead to a satisfactory solution.

From Kawahito et al.: In Phase I Ex Vivo Studies of the Baylor/NASA Axial Flow Ventricular Assist Device, in: Heart Replacement Artificial Heart 5, pages 245 – 252, Springer Verlag Tokyo 1996, Publisher T. Akutso and H. Koyagani, an axial blood pump according to the state of the art for the support of an ill heart is known, which can be implanted into the chest area of a patient. The axial blood pump has a rotating



impeller with a blading, which is supported within a blood carrying pipe and is driven by means of an electric motor.

For this the impeller is formed as a rotor of the electric motor and is coupled by means of magnets mounted on the blading with the stator of the electric motor fast with the housing. An axial and a radial support of the rotor takes place via a toe bearing, in which the rotor is supported point-by-point on bearing elements arranged in the flow. Such an arrangement is also known from US A 4,957,504.

The known blood pump has the disadvantage, that the blood to be delivered experiences in a considerable extent a traumatisation and damage. In this case the danger lies generally in the formation of thrombi. The reason for this lies essentially in the formation of wake areas of the bearings. A further disadvantage is undoubtedly the limited endurance of the mechanical bearing because of wear.

US-Patent 4 779 614 discloses an implantable axial blood pump, which consists of an outer cylindrical pipe and a rotor hub rotating in this pipe for the blood delivery. The rotor is magnetically supported and carries at the same time the rotor magnets of the drive and the impeller blades. The magnetically supported rotor forms with the stator blading mounted on the outer pipe long, narrow gaps. The arrangement of two motor-stator-combinations respectively on the ends of the pump shall stabilise the positioning of the rotor. The positioning in the direction of the axis is stabilised by another pair of magnets, which shall take up the axial forces of the rotor as well. Although a relatively wide annular gap for the fluid flow is provided and with the magnetic bearing of the rotor important development goals for the implantable blood pump concerning a compact design and free from sealing and support problems can be aimed at, the blood pump has great disadvantages concerning the function and the structural design of the pump. The exceptionally long narrow gaps between the rotor hub and the stator blades on the stator increase the danger of blood damage by high velocity gradient of the gap flows. The arrangement of two motors required for the rotor stabilisation is designwise cumbersome. Furthermore, the rotor is not form-fittingly secured in the axial direction and is therefore a residual risk.



The US-Patent 5 385 581 also discloses an axial blood pump with magnet bearing. The bearing magnets arranged in the rotor and in the stator area are charged with an opposing polarity.

Disadvantageously this leads to the breakdown of the pump, when the bearing fails. Furthermore, it is disadvantageous that no so-called post guide lattice is provided, i.e. the total pressure is produced by the impeller, and the residual spin energy remains in the flow.

A further axial blood pump with magnetic bearing is known from WO97/49 440. The magnetic bearing is carried out at the conically formed rotor ends of the rotor, which forms the impeller. The fixedly arranged pole shoes are arranged opposite to the rotor ends, which pole shoes guide the flow of the permanent magnets. The bearing necessitates an active stabilisation with at least four stabilisation coils in axial as well as in radial direction. In a further variant the bearings with radially magnetised permanent magnet rings with changing magnetisation direction are proposed, which are indeed difficult to control.

From WO 98/11 650 a further axial blood pump with a so-called bearingless motor is known. The "bearingless" motor is a combination of a motor and a magnetic bearing. The position of the rotor is stabilised passively by permanent magnets with reference to three degrees of freedom - translation in the x-direction, tipping in the x- and y-direction - . The passive stabilisation is achieved by a permanent magnetic rotor ring, which is surrounded on the stator side by a soft iron ring. Control- and driving coils, which are connected to the soft iron ring, allow a drive with reference to three degrees of freedom. The low bearing stiffness requires additional measures. Furthermore, a bearing stabilisation is necessary in the x- and y- direction, which leads to a great extent of measuring technology to be applied and can result in a high heating of the pump because of the active coils.

For the delivery of chemical fluids an axial propeller pump is known from EP-A 0 856 666. The delivery element is magnetically supported between two mounting elements, which are attached in a tubular hollow body with the retention of an annular element. The delivery element forms the rotor of a motor, which stator is arranged externally of the tubular hollow body. The magnetic bearing is achieved in the radial



direction by radial magnetised permanent magnets and in the axial direction by means of electromagnetic coils, which as far as possible are decoupled from these. Radially magnetised permanent magnets necessitate a defined minimum size and small air gaps.

Therefore, the delivery gap can only be very small, which in the here present delivery task (propeller pumps produce a high pressure at a small delivery volume) which is not a hindrance for other pumps, but, however, is especially not acceptable for blood pumps. Furthermore, the complete axial rigidity, which is very high compared to the radial rigidity because of the delivery pressure of the to be delivery medium, has to be exerted by the stabilisation coils, which requires a specific current value, which leads to a corresponding energy demand and to heating. The control of the axial position slows down with increasing current value, so that the pump is only suitable for pulsating delivery tasks to a limited extent.

It is the object of the invention to provide a device for the gentle delivery of single- or multiphase fluids of a simple structural design, which does not or only inconsiderably change the to be delivered fluid in its characteristics, in which wake areas and vortexing of the to be delivered fluid are minimised and a pulsating delivery is enabled.

The object is addressed according to the characterising features of claim 1.

Preferred and advantageous embodiments of the invention are given in the sub-claims.

According to this the delivery element is supported free of contact between the mounting elements, respectively separated to each by a hub gap, by means of permanent magnetic bearing elements, which are arranged in the mounting elements as well as in the delivery element, which functionally work together and which magnetic acting faces are opposed to each other and are magnetised in the axial direction and poled oppositely. Sensors for the positional detection and stabilisers for the positional correction are arranged in the mounting elements and on or in the wall of the hollow body.



The device according to the invention achieves a simple design. The permanent magnetic bearing elements necessary for the magnetic bearing, are additionally arranged to the permanent magnetic elements of the motor rotor directly on the delivery element. The magnetic bearing takes up advantageously the axial as well as the radial forces. The axial stabilisation offers an active control of the axial position of the delivery element, wherein annular coils, arranged on the front face of the delivery element, produce an axial magnetic flow, which superimposes the axial magnetic flow of the permanent magnetic bearing elements and serves for the control of the axial position.

The rotor gap, which has to be provided between the external face of the delivery element and the inner face of the tubular hollow body, has to be designed in such a way, that the motor losses as well as the flow losses generated by the gap are minimised. Hereby it is important, that the generated motor losses are increasing the further away the motor rotor is arranged from the motor stator. A smaller rotor gap on the side of the motor is to be seen as advantageous. On the other hand a smaller rotor gap leads, however, to larger friction losses of the flow and therefore, is technologically disadvantageous concerning the flow. A suitable compromise for blood pumps lies for example in the named rotor gap width of 0.5 to 2.5 mm.

An advantageous embodiment of the invention consists in that further sensors for the determination of the instantaneous blood volume flow and for the instantaneous pressure difference generated by the pump are integrated in the hubs of the axial blood pump and/or in the walls of the tubular hollow body. Both measuring values are present in the controller of the delivery device for the variance comparison and therewith opens the possibility for a control of the delivery process in the sense of a physiological optimal pulsating delivery, adapted to the natural heart action by means of a time dependent rotational speed change of the rotor or of a pulsating pump optimised in the sense of a lower energy consumption and also realised by a time dependent rotational speed change.

In a preferred way the mounting elements are formed as fluid guide units with fluid blades. Because of this flow losses are minimised.



In a further advantageous embodiment of the invention means are provided on the front face of the rotor hub, which deliver radially the fluid present in the hub gap between the fluid guide unit and the delivery element to the outside, for example radial blades, grooves, bulgings or convex formations.

A further advantageous embodiment of the invention consists in that an axially extending bore is provided in at least one of the fluid guide units, through which the to be delivered fluid passes, and which serves, that fluid present in the hub gap between the fluid guide unit and the delivery element is transported radially to the outside.

Both prementioned embodiments influence the radial pressure distribution and produce compensation flows for the prevention of dead water areas in the hub gap between the front faces of the fluid guide unit and the delivery element.

In a further embodiment of the invention the delivery element, especially the rotor hub, has two blades distanced in the axial direction. Herewith a so-called tandem grid is formed.

The pressure increase to be produced by each blading row is advantageously reduced. Furthermore, this special arrangement of the rotor of the delivery device limits additionally the disturbing tipping movement of the same.

Following the invention is described in detail by means of an example with reference to the figures.

Fig. 1 shows a sectional view of an axial blood pump;

Fig. 2 shows a longitudinal sectional view of an axial delivery device with a magnet bearing, axial stabilisation and positioning sensory mechanism;

Fig. 2a shows a sectional view of the axial delivery device along the line A-A of Fig. 2;



Fig. 2b shows a longitudinal sectional view of an axial delivery device with magnetic mounting;

Fig. 2c shows a sectional view of the axial delivery device along the line A-A of Fig. 2b;

Fig. 2d shows a longitudinal sectional view of an axial delivery device with a conical delivery element;

Fig. 3a shows a magnetic mounting for an axial delivery device;

Fig. 3b shows a cross sectional view of the magnetic mounting of Fig. 3a;

Fig. 4 shows a delivery element with double blading;

Fig. 5 shows a fluid guide unit with positioning sensor and permanent magnet bearing element;

Fig. 5a shows a sectional view of the fluid guide unit along the line B-B of Fig. 5;

Fig. 6a shows a schematical front view of the front face of a rotor hub or hub;

Fig. 6b shows a schematical front view of the front face of a further rotor hub or hub;

Fig. 6c shows a schematical front view of the front face of a rotor hub or hub with an eccentric projection;

Fig. 7 shows a schematical sectional view of a hub gap, formed between delivery element and hub of a mounting element;

Fig. 7a shows a schematical sectional view of a hub gap, formed between delivery element and hub of a mounting element; and

Fig. 8 shows a schematical sectional view through a hub with an axial bore.



Fig. 1 shows an exemplary embodiment of a blood pump according to the invention having a pump housing 3 and a stabilizer housing 2. A motor stator 31 with a motor winding 33 is arranged outside and around a tubular hollow body 1, in which in axial direction the fluid is delivered. The motor stator 31 drives a delivery element 5, comprising a motor rotor 32 and a rotor hub 52 and which is supported inside the tubular hollow body 1. The rotor hub 52 has a rotor blading 53. In the flow direction, in front of and behind the rotor hub fluid guide units 7, 7' with fluid guide blading 72, 72' are mounted on the inner wall of the tubular hollow body 1. Between the fluid guide units 7, 7' and the rotor hub 52 a so-called hub gap 9 is formed. The motor rotor 32 combined with the rotor hub 52, can be rotated via the motor stator 31.

During the operation of the blood pump the discharged blood is carried through an elbow 6 to the delivery element 5 and there is rotated by means of the rotor blading 53, wherein the rotor hub 52 serves for producing advantageous flow dynamical conditions. A flow technical advantageous flow against the rotor blading 53 is provided by the fluid guide unit 7' with its blading 72' rigidly connected upstream of the hollow body 1. The pressure sensor 60 allows a pressure measuring in the inflowing fluid. The delivery element 5 is in the known way driven by magnetic coupling of the motor rotor 32 with the motor stator 31. A forming of thrombi in blood as the delivered medium is greatly minimised, as no bearing elements are arranged in the flow, which could cause wake areas, because of the magnetic bearing. A vortexing and therewith connected flow losses only appear in a small extent. A rotor gap 8 between the rotor hub 52 and the inner wall of the hollow body 1 has in this case a width, which keeps the flow losses small and at the same time also limits the motor losses, which increase with increasing distance of the motor rotor 32 to the motor stator 31. A width of the rotor gap 8 of between 0.5 to 2.5mm has shown to be especially advantageous. After the acceleration of the fluids by the rotor blading 53 of the rotor hub 52 and a therewith connected pressure build-up, the fluid is guided into the fluid guide unit 7, where it experiences a deflection in the axial direction and further a pressure increase is carried out. Because of the design of the fluid guide blading 72 of the fluid guide unit 7 it is secured, that the deflection of the fluid in the axial direction is carried out gently and also essentially without vortexing.



The blood leaves the blood pump via the elbow 6' and flows into an aortic cannula 62, which is attached by means of a releasable connection element 63 on the elbow. A specially shielded cable 11a, comprising the supply and signal lines for the motor stator 31, the axial stabilizer 12 and the sensory mechanism 60, 61 and 43, is connected via the cable muff 11 with the blood pump.

The function of the magnetic bearing is described by means of Fig. 2 and 2a.

Fig. 2 and Fig. 2a show, furthermore, in the longitudinal sectional view and in the sectional view, respectively, a further embodiment of a blood pump having a magnetically supported rotor hub 52. In the rotor hub 52 the motor rotor 32 is integrated, having permanent bearing elements 42 arranged at its ends, which are supported in a mounting 4. In the fluid guide units 7, 7' permanent magnet bearing elements 41 are arranged directly opposite permanent magnet bearing elements 42. In this case the permanent magnet bearing elements 41 and 42 are charged with an opposed polarity. The axially directed attraction force arising between the permanent magnet bearing elements 41, 42 ensures that the delivery element 5 is held coaxially in the tubular hollow body 1 and that radial deflections are corrected. Positioning sensors 43 also arranged in the fluid guide units 7 and 7', determine the width of the hub gap 9 and measure and control this gap by means of the axial stabilizer 12. The axial stabilizer 12 is arranged in a stabilizer housing 2. The axial stabilizers 12, formed as windings, produce, when the current supply is switched on, a magnetic field, which is transmitted via the stabilizer housing 2 and the flow guide elements 10 in such a way, that the delivery element 5 takes up a stable axial position between the fluid guide units 7 and 7'. At the ends of the fluid guide units 7 and 7', as well as on the outer wall of the tubular hollow body 1, pressure sensors 60, as well as a flow sensor 61 for the characterisation of the flow are attached. The delivery element 5 comprised of the motor rotor 32 and the permanent magnet bearing elements 42, as well as of the rotor blading 53, is rotated by means of the motor stator 31. Radial variations during the rotation are levelled-out by the opposingly charged permanent magnet bearing elements, while the axial stabilisation is carried out via the positioning sensors 43 and the axial stabilizers 12. The concentration of the main mass of the permanent magnet bearing elements 42 in the area of the axle of the delivery element 5 makes it possible to drive the pump in a pulsating operation, e.g. by a fast change of rotational speed of the rotor.



The permanent magnet bearing elements 41 and 42 are alternatively formed as permanent magnet rings also having an axial magnetisation instead of as a solid cylinder. Any embodiments, known to the specialist, can be used for the exact design of the permanent magnet bearing elements 41 and 42.

For a stabilisation of the axial positioning of the delivery element 5 and of the rotor hub, respectively, an axial stabilizer 12 is provided in the embodiment as an example, which interacts with positioning sensors 43 and which acts via the fluid guide units 7 and 7' on the end faces of the delivery element 5, respectively, and uses an electronic control circuit, not represented in this case. The axial stabilizer 12 causes an active control of the axial positioning of the delivery element 5, wherein the stabilizer windings are acted upon by currents according to the carried out control and causes at the same time a magnetic flow, which overlays the axial magnetic flow of the permanent magnet elements and serves for the control of the axial positioning. The positioning sensors 43 determine variations from the desired axial position of the delivery element 4 and transmit this information to the control circuit.

Fig. 2b and Fig. 2c show a longitudinal sectional view and a sectional view of a further embodiment of a device according to the invention. The mountings 75 provided in front of and behind the delivery element 5 viewed in the flow direction, consist of a hub 73, mounted with supports 74 on the inner wall of the tubular hollow body 1. The supports 74 are arranged here for example around the hub 73 at a distance of 90°. In general one support 74 would also be sufficient. The mounting 75 serves essentially for receiving the permanent magnet bearing elements 41. The opposed permanent magnet bearing elements 41 and 42 are also charged with opposing polarity, in this case. For the axial stabilisation the axial stabilizer 12, the positioning sensor 43 and a control electronic, not represented, are used.

In a further embodiment of Fig. 2d the delivery element 5 and the fluid guide unit 7 are formed conical. A conical rotor 80 of the delivery element 5 expands in flow direction and merges, further conically expanding, in a conical guide unit 81. The permanent magnet bearing elements 41 and 42 are charged with opposing polarity.



The axial stabilisation is also carried out via the positioning sensors 43 in connection with the axial stabilizer 12.

Figures 3a and 3b show, respectively, a longitudinal sectional view and a sectional view in detail an exemplary embodiment of the mounting 75 with supports 74.

Fig. 4 shows a delivery element 5 with the rotor hub 52 arranged around the two rotor bladings 53 and 53'. The arrangement of two or more rotor bladings 53 makes it possible, to increase the effect of the blading of the delivery element 5.

Fig. 5 and Fig. 5a show a longitudinal section view and a sectional view, respectively, of the fluid guide units 7 or 7', respectively, in which the permanent magnet bearing element 41 is surrounded by the positioning sensor 43.

Measures, which influence the radial pressure distribution and generate compensation flows for the prevention of dead water areas in the area of the rotor hub 52, i.e. in the hub gap 7 between the front faces of the fluid guide unit 7 and 7' and of the delivery element 5, are shown in Figures 6a, b, c, 7 and 7a. According to Fig. 6a a rib 723 extending radially to the outside from the centre, is arranged on a front face 722 of the fluid guide unit 7, 7'.

According to Fig. 6b the rib 724 is formed curve-like. Instead of such ribs also convex and/or concave projections, radial bladings, micro-bladings, ribs, recesses and eccentric projections 725 (Fig. 6c) of any form on the front face 722 or even simply a roughness of the upper face can be provided. Important is only, that these are means, by which the fluid can be delivered out off the hub gap 9 (compare Fig. 8) at rotation of the delivery element 5. These means can, of course, also be arranged on the front face of the rotor hub 52.

The representation according to Fig. 7 causes advantageously additionally an improvement of the resistance to galling in case of failing of the axial stabilisation.

In Fig. 8 the hub 73 has an axial bore 726, through which the to be delivered fluid flows und which causes, that the fluid remaining in the hub gap 9 is additionally transported radially.



It is stressed that the magnet bearing according to the invention is not limited to cylindrical forms of the magnets. Other geometric designs of the permanent magnet bearing elements 41 and 42 are possible.

It will of course be realised that the above embodiments have been given only by way of illustrative example of the invention and that all such modifications and variations thereto, as would be apparent to persons skilled in the art, are deemed to fall within the broad scope and ambit of the invention as is herein set forth in the claims that follow.



Reference numerals list

1	Tubular hollow body
2	Stabilizer housing
3	Pump housing
4	Mounting
5	Delivery element
6	Elbow
6'	Elbow
7	Fluid guide unit
7'	Fluid guide unit
8	Rotor gap
9	Hub gap
10	Flow guide element
11	Cable muff
11a	Cable
12	Axial stabilizer
31	Motor stator
32	Motor rotor
41	Permanent magnet bearing element
42	Permanent magnet bearing element
43	Positioning sensor
44	
45	
51	
52	Rotor hub
53	Rotor blading
60	Pressure sensor
61	Flow sensor
62	Aortic cannula
63	Connection element
72	Fluid stator blading
72'	Fluid stator blading
	Hub



74	Support
75	Mounting
76	Hub cap
722	End face
723	Rib
724	Rib
725	Projection
726	Bore
80	Conical rotor
81	Conical guide unit



The claims defining the invention are as follows:

1. A device for the gentle delivery of single- or multiphase fluids, comprising a tubular hollow body, guiding the fluid essentially axially, in which a delivery element which can be rotated by a motor stator arranged outside the hollow body, is supported axially positioned, wherein the fluid is transportable in the rotor gap between the delivery element and the hollow body, and wherein one mounting element is mounted in front and behind the delivery element, respectively,

characterised in that

the delivery element is supported free of contact between the mounting elements, separated each by a hub gap, by means of permanent magnetic bearing elements which are arranged in the mounting elements as well as in the delivery element and functionally work together and are opposingly with their magnetically acting faces and which magnetic bearing elements are magnetised in the axial direction and are oppositely poled and in that sensors and stabilizers for the determination of the position and the correction of the position of the delivery element are arranged in the mounting elements and on or in the wall of the hollow body.



2. The device according to claim 1, characterised in that for the flow characterisation pressure sensors and flow sensors are arranged in the mounting elements and/or on or in the wall of the hollow body.
3. The device according to either claim 1 or 2, characterised in that the bearing elements have flow guide elements, which are arranged in the mounting elements.
4. The device according to any one of claims 1 to 3, characterised in that the mounting elements are formed as fluid guide units with fluid bladings.

The device according to any one of claims 1 to 4,



characterised in that

on the end faces of the mounting elements facing the delivery element and/or on the end faces of the delivery element, ribs, bladings, grooves, convex and/or concave protuberances or eccentrically arranged projections are provided.

6. The device according to any one of claims 1 to 5, characterised in that an axially extending bore is arranged in at least one of the mounting elements.
7. The device according to any one of claims 1 to 6, characterised in that the rotor hub of the delivery element has two rotor bladings, arranged with axial distance.
8. The device according to any one of claims 1 to 7, characterised in that the rotor hub and the hubs are formed cylindrically and that the hubs at the end facing away from the delivery element are closed by hub caps.
9. The device according to any one of claims 1 to 8, characterised in that the delivery element and the mountings, also when designed as fluid guide units, are formed non-cylindrically enlarged or diminished in the flow direction.
10. A device substantially as hereinbefore described and/or illustrated in any one or more of the accompanying figures.

DATED THIS FOURTH DAY OF DECEMBER 2002

Berlin Heart AG

BY

PIZZEYS PATENT AND TRADE MARK ATTORNEYS



DE 10 2004 000 000 A1

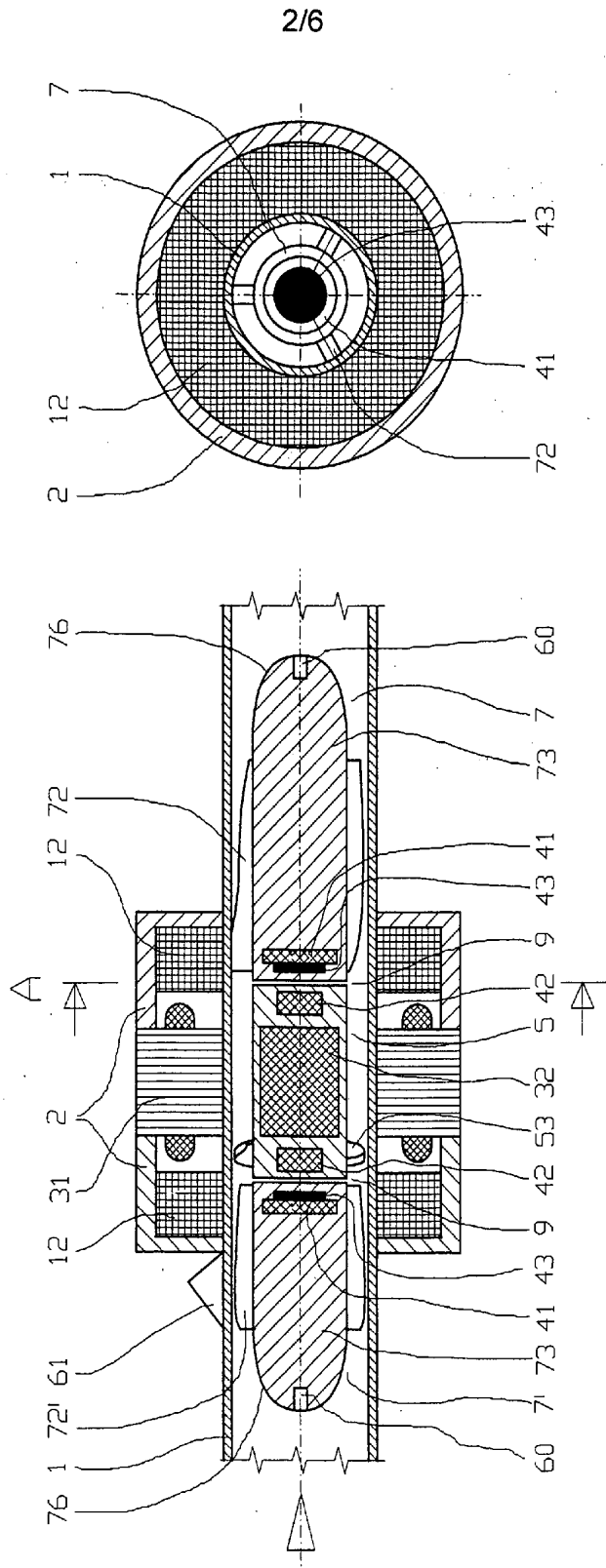


Fig. 2a
Schnitt A-A

A FIG. 2

DE 10 2004 000 000 A1

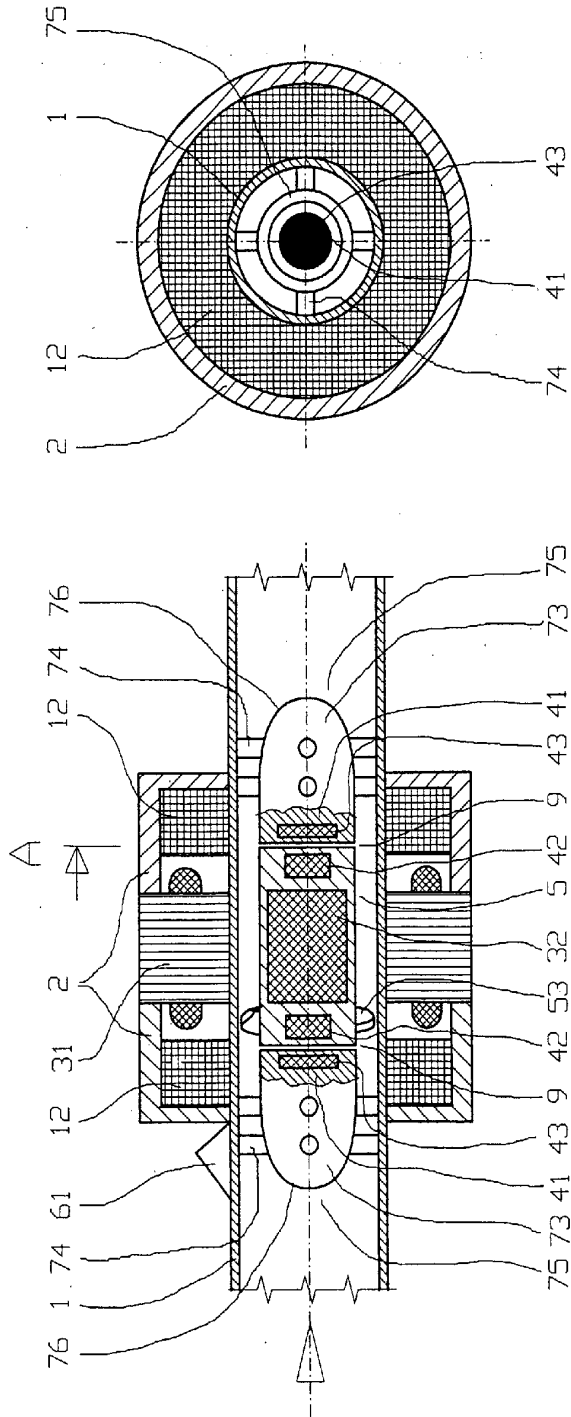


Fig. 2c
Schnitt A-A

Fig. 2b

07 01 02 10507

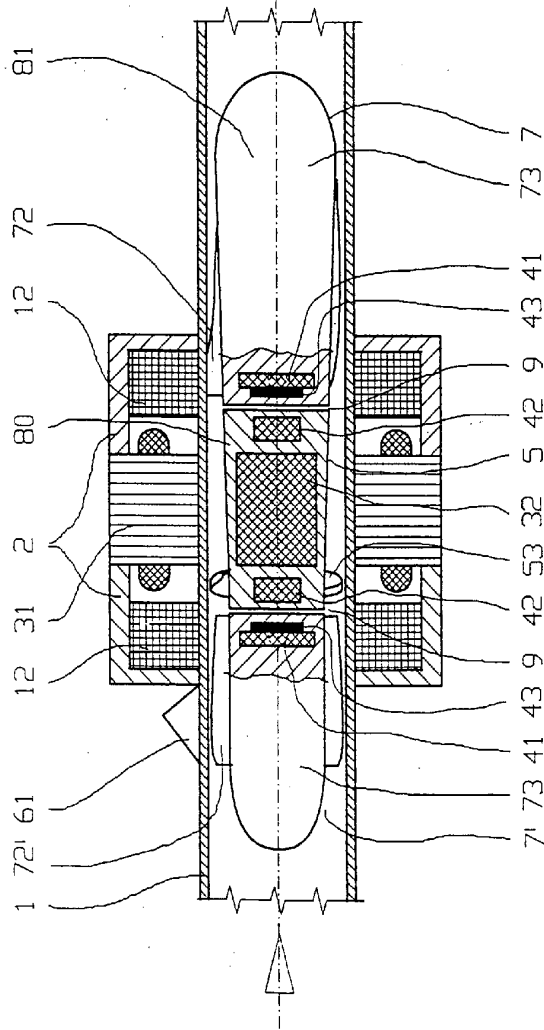


Fig. 2d

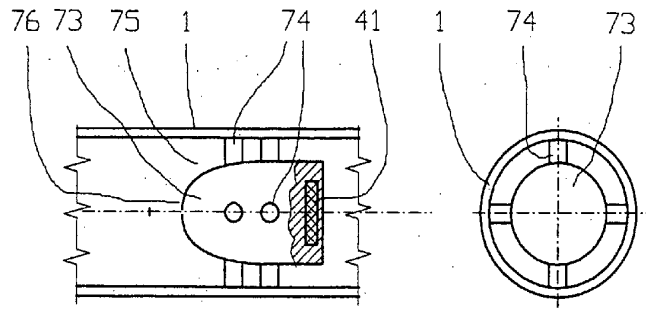


Fig. 3a

Fig. 3b

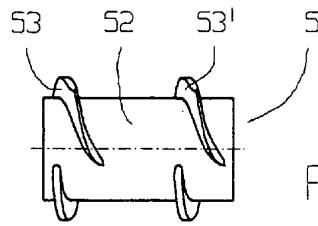


Fig. 4

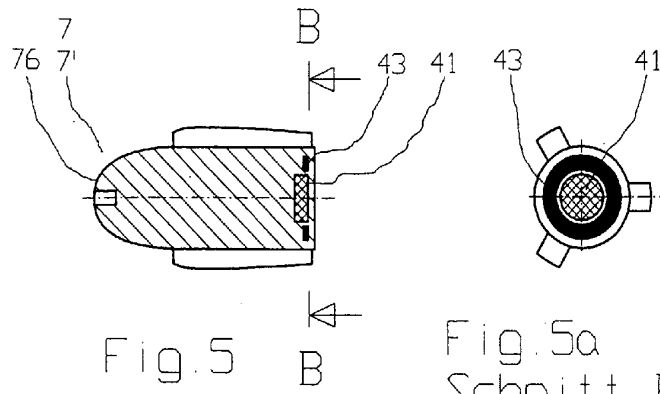


Fig. 5

Fig. 5a
Schnitt B-B



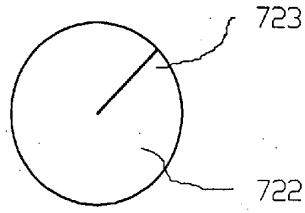


Fig. 6a

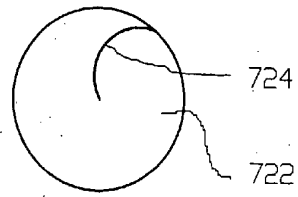


Fig. 6b

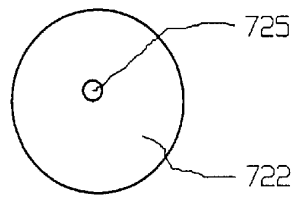


Fig. 6c

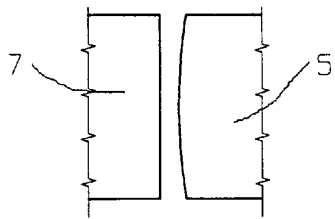


Fig. 7

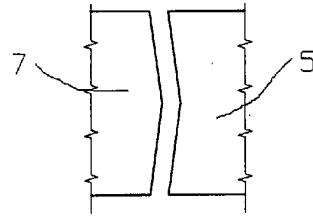


Fig. 7a

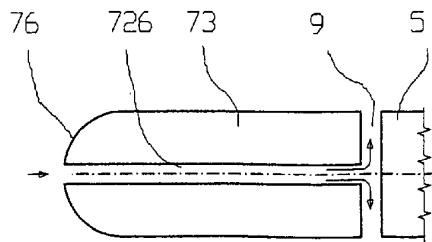


Fig. 8