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(54) Liquid centrifuging device and centrifugation member

(57) This device for centrifugation of a liquid comprises a stationary portion (10'), a processing chamber (3) rotatably mounted with respect to said stationary portion for rotation about a predetermined axis, a multi-chanel flexible tubing (9), one end of which being fixed with respect to said stationary portion substantially along said predetermined axis, with the other end of said flexible tubing being attached substantially on said axis in rotationally locked engagement to the processing chamber (3) and a supporting means (36) to prevent any substantial elongation of said tubing (9) due to the centrifugal forces to which it is submitted during rotation of said processing chamber (3). Said multi-chanel flexible tubing (9) is sheathed with a coil spring (35) which is solid with it, from said one end to said other end of said flexible tubing (9), to prevent any direct contact between the latter and said supporting means (36).

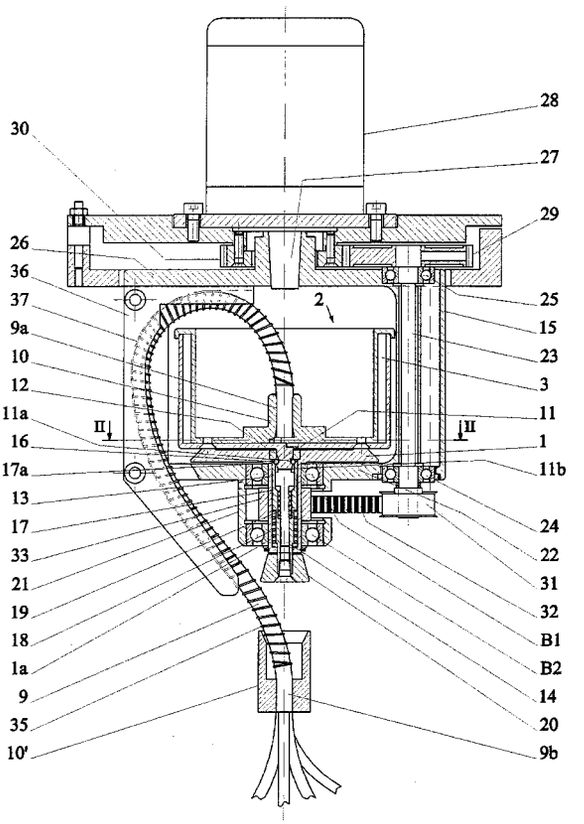

Fig. 1

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Description

[0001] The present invention relates to a device for centrifugation of a liquid comprising a stationary portion, a processing chamber rotatably mounted with respect to said stationary portion for rotation about a predetermined axis, a multi-chanel flexible tubing one end of which being fixed with respect to said stationary portion substantially along said predetermined axis, with the other end of said flexible tubing being attached substantially on said axis in rotationally locked engagement to the processing chamber and a supporting means to prevent any substantial elongation of said tubing due to the centrifugal forces to which it is submitted during rotation of said processing chamber and to keep the tubing with a shape having radii of curvature large enough for improving the rotation of the tubing around its longitudinal axis. This invention also relates to a centrifugation member.

[0002] Such a liquid centrifuging device comprising a rotor assembly for receiving liquid to be processed by centrifugation has already been disclosed e.g. in US 4'113'173. Liquid communication is maintained with the rotor assembly during rotation of the latter by means of a flexible umbilical duct element which extends from the rotor assembly to a location external to the apparatus by way of a passageway provided in the support shaft of the rotor assembly and a guide sleeve carried on and rotatably mounted to the rotor drive assembly. The rotor assembly is rotatably driven in the same direction as the rotor drive assembly with a speed ratio of 2:1 to prevent the umbilical duct element from becoming completely twisted during the operation of the apparatus. A guide sleeve is provided on the rotor drive assembly to support the umbilical duct element during operation. The tubing forming the multi-chanel flexible tubing is submitted to various stresses. The first one is an alternate bending due to the fact that one extremity of the tubing is fixed, whereas the other extremity is solid with and coaxial to the rotor assembly. It has already been proposed, particularly in WO 00/61295, a low diameter rotor assembly which is able to spin at approximately 5'000 t/min, so that the tubing is submitted to a very high frequency repeated bending stresses. These repeated bending stresses extending on the whole liquid processing, lasting possibly up to several hours. In order to prevent over heating and early destruction of said tubing, the latter has to be extruded in a soft plastic material. However, the drawback of a soft plastic material is to render the tubing less resistant to torque reaction, and thus to substantially diminishe its capacity to transmit a torque able to overcome the friction forces with the supporting surfaces intended to prevent any substantial elongation of said tubing due to the centrifugal forces to which it is submitted during rotation of said processing chamber. The tubing will thus present a torque reaction more important as it made from a softer plastic material, possibly completely collapsing the multi-chanel inside said tubing.

[0003] The second stress is due to the centrifugal force exerted on the tubing, proportional to the square of its rotational speed. At 2'500 t./min, centripetal acceleration to which the tubing is submitted is equal to approximately 350 times terrestrial gravitation. This heavy acceleration requires the utilisation of a support element for sustaining the tubing while rotating, so that it doesn't elongate until breaking, or that it doesn't adopt an unfavourable shape for its duty of alternate bending (e.g. as having locally too small curvature radius).

[0004] However, it is known that the friction coefficient of a soft plastic material against any rigid material can only be high. This implicates that friction of the soft plastic tubing against the support element would cause a substantial heating, and finally an early material injury.

[0005] It is important to point out that the two problems are intimately bounded. In fact, when the system is set in rotation, the heavy increase of the centrifugal force on the tubing induces an increase of the friction torque between the tubing and its support element proportional to the variation of the centrifugal force. This friction torque is contrary to the alternate bending work of the tubing and therefore creates a torque reaction on the tubing. The more the plastic material of the tubing is soft the more the torque reaction of this tubing will increase.

[0006] The important friction torque between the tubing and its support element induces also a notable heating of the tubing, softening the plastic material from which it is formed (lowering the Shore's hardness) and, finally, implicates a more and more elevated torque reaction of the tubing up to the complete collapse of the multi-chanel inside the tubing, or even the breaking of the tubing.

[0007] It has already been proposed in US 4'299'256 a flexible coextruded tubing having an outer portion of polyvinyl chloride plastic containing a minor amount of intimately mixed silicone oil and having an inner portion of plastic free of silicone in order to improve the frictional resistance of tubing, while at the same time the interior of the tubing remains unchanged.

[0008] Such a coextruded plastic tubing is relatively expensive to produce and allows neither to increase enough the torque resistance of the tubing, nor to regularize the radius of curvature of the tubing where it does not rest against a supporting surface, thus allowing elevated constraints to be locally exerted on the tubing. Furthermore it does not prevent the attrition of the tubing.

[0009] It has also already been proposed in US 4'710'161 to surround such a plastic tubing which is rotatably held on a bearing carried on and rotatably mounted to a rotor drive assembly by a coil spring, the both ends of which are respectively fixed to a centrifugal rotor assembly and to said bearing at the portion thereof fixed to said tubing. Such a coil spring is intended to transmit the torque from the centrifugal rotor assembly to said bearing in order to substantially cancel relative angular

movement between said tubing and said bearing, so that there is practically no friction between tubing and bearing. The coil spring according to this reference is not solid with the tubing and does not rest against a supporting surface of the tubing.

[0010] The aim of the present invention is to make it possible to provide means able to reduce the friction torque between the tubing and a supporting surface and, in the same time to reinforce the tubing with respect to the centrifugal force which exerts on it during the centrifugal processing, without increasing the bending strengh of this tubing.

[0011] To this end, one object of the invention is a centrifugal liquid processing apparatus according to claim 1. Another object of this invention is a centrifugation member according to claim 10.

[0012] The advantage of the coil spring sheathing the tubing and solid with it on its whole length, according to the present invention is on the one hand, to avoid the friction between the soft plastic material of the tubing and the hard material of the supporting surface of this tubing as well as to reduce the friction area with this supporting surface and on the other hand, to uniformly reinforce the tubing all along its length, thus substantially reducing the risk of localised constraints exerted on the tubing during centrifugal processing. Another advantage of the invention is that the tubing is guided by supporting means. These supporting means allows to keep the related angular position and the radius of the tubing unchanged during the rotation of the rotor assembly, so that this rotor assembly may be poised with a very high precision. This feature is essential for a high speed rotor assembly.The appended drawing illustrates, schematically and by way of example, one embodiment of the centrifugal processing apparatus which is the subject of the present invention.

Figure 1 shows a sectional elevated view of this embodiment;

Figure 2 shows a partial section view along line II-II of Figure 1;

Figure 3 shows a sectional enlarged view of the tubing of Figure 1.

[0013] The centrifugation device illustrated in Figure 1 is substantially similar to that disclosed in WO 00/61294 and is intended especially for blood apheresis and includes a centrifugation rotor having the shape of a disk 1 comprising a central tubular element 1a, mounted so as to pivot in two sets of ball bearings, B1, B2. This centrifugation rotor 1, carries a disposable centrifugation cup 2 in which is formed a ring-shaped processing chamber 3 connected to a tubular housing 10 formed coaxially to the rotation axis of the cup 2 by a plurality of radial channels 4, 5, 6, 7 shown in Figure 2, provided through the bottom of the cup 2. Such a disposable cup 2 is known and it is not necessary to disclose it more for understanding the present invention, more especially as it is already completely disclosed in the above-mentionned WO 00/61294 to which it is possible to refer.

[0014] The disposable cup 2 is connected in a non-mobile way to the centrifugation rotor 1 in the manner described below.

[0015] The bottom of the cup 2 includes a coupling element consisting of a cylindrical shank 11, that has a groove 11a with a semi-cylindrical cross-section, adjacent to a truncated end 11b. This coupling shank 11 engages with a coupling ring 12 of a coupling tube 13, which are housed in the tubular 1a of the centrifugation rotor 1.

[0016] The coupling tube 13 includes a coupling device, which, in this embodiment, consist of a ball ring 16, located at the inner end of the axial passage formed by the ring 12, connected to the tubular part 1a of the rotor 1. A tubular piston 17 is mounted so as to slide in the tubular part 1a. Its upper end is terminated by a funnel-shaped surface 17a. This tubular piston 17 is pressed axially against the inner end of the ring by a coil spring 18, which is pressed between one end of the tubular part 1a of the rotor 1, and a bearing surface of the tubular piston 17. This axial pressure in the direction of the ring 12 and the funnel shape 17a have the effect of exerting centripetal forces on the ball ring 16, which press them into the groove 11a of the coupling shank 11 of the disposable cup.

[0017] In order to prevent that these balls enter in the axial opening of the ring 12, during removal of the coupling shank 11, a second piston 14 is mounted so as to slide inside the tubular piston 17 and a second coiled spring 19 pushes it axially against the end of the coupling shank 11.

[0018] The outer end of the tubular piston 17 is connected to a grasping element 20 to permit axial traction to be applied opposite to the pressure of the spring 18, in order to permit the balls 16 to move outward. The piston 14, subject to the axial pressure of the spring 19 can then eject the cup 2 upward and simultaneously hold the balls 16 apart.

[0019] The ball bearings B1, B2 of the tubular part 1a of the rotor are mounted in a support element 21 attached to a plate 22, which is attached in turn to an upper disk 26, by two verical hollow supports 15. A drive shaft 23 is mounted inside one of these hollow supports 15 so as to pivot by means of two ball bearings 24, 25 attached respectively to the plate 22 and to an upper disk 26, located above the cup 2. This upper disk 26 is attached to a drive shaft 27 of a motor 28, coaxial with the axis of rotation of the rotor 1. An end of the shaft 23 extends above the disk 26 and is attached to a satellite gear 29 in mesh with a fixed gear 30 coaxial to the axis of the rotor 1. The ratio between the diameters of the satellite gear 29 and the fixed gear 30 is 1:1, so that if the rotation velocity of the plate 26 is ω, that of the shaft 23 about its axis is 2ω. The lower end of this shaft 23 carries a gear-wheel 31, connected by toothed belt 32 to a gear-wheel 33 of the same diameter as the gear-

wheel 31, so that the rotor 1 is driven at velocity 2ω.

[0020] The radial channels 4, 5, 6, 7 provided through the bottom of the cup 2 are connected to four conduits, 4a, 5a, 6a and 7a respectively (Figure 3), which are arranged in parallel in a single flexible tubing 9. In the disclosed embodiment, there are four radial channels 4, 5, 6, 7 connected to four conduits 4a, 5a, 6a, 7a. However, obviously, the invention is not limited to such a number of channels and conduits. The cross-sections of the conduits 4a and 6a having the larger section areas are elliptical, the major axes of these ellipses being tangent to at least one circle that is concentric to the longitudinal axis of tubing 9. This orientation of the elliptical sections of conduits 4a, 6a facilitates the rotation of the tubing about its longitudinal axis.

[0021] The flexible tubing 9 forms an open loop, one end 9a of which is attached and held in the tubular housing 10 whereas the other end 9b is attached and held in a tubular adaptation housing 10', substantially similar to the housing 10 supporting the first end of this tubing 9 and fixed and coaxial to the axis of rotation of the rotor 1. These two ends 9a, 9b are preferably glued in the housings 10, 10'.

[0022] Between these two ends 9a, 9b attached to the housings 10, 10', the flexible tubing is sheathed by a coil spring 35 which is solid with this tubing on its whole length. To this end, the coil spring may be avantageously glued around the tubing. The gluing material must, in any case, not substantially lowering the flexibility of the tubing. According to an embodiment of the invention, if the tubing is manufactured with a sufficiently flexible PVC to allow alternate bending constraints, preferably with a PVC with rigidity in the range of 50 to 75 ShA, moreover the disposal of such a material being made easy. The gluing material may avantageously be a cyanolit type adhesive material.

[0023] The internal diameter of coil spring 35 must be slightly larger than the external diameter of the tubing 9 in order to prevent pre-constraints, detrimental to the bending work of the tubing. According to a prefered embodiment of the invention, the tubing has a diameter of 6,0 mm whereas the coil spring has an internal diameter of 6,1 mm.

[0024] The winding direction of the coil spring 35 has to be the same than the rotation direction of the centrifugation rotor 1.

[0025] Avantageously, the coil spring 35 is made of stainless steel so that it is simple and cheap to manufacture, and the disposal of such a material is made easy. It could be also made of hard plastic material such as hard PVC, PC or PMMA.

[0026] The dimensions of coil spring 35 must be selected in order to remain as light as possible so as to exert on the tubing a centrifugal force as low as possible. The better experimental results have been obtained with a wire section diameter of the coil spring comprised between 0,1 to 0,6 mm, preferably a diameter of 0,4 mm, with a coil pitch comprised between 1 to 5 mm, avantageously a coil pitch of 2 mm for a tubing diameter comprised between 3 and 12 mm. These dimensions allows sufficent support of tubing 9 and prevent any bead formation between adjacent coils.

[0027] A support 36, provided with a curved guiding channel 37 having a semi-circular cross-section for receiving the flexible tubing 9 sheathed by the coil spring 35, is attached under the upper disk 26. This support 36 is made in a material having a low friction coefficient and a low attrition rate with the material of the coil spring 35. Avantageously, it is made in Vaflon® (Dixon Resine) which is a PTFE and polymer mixture, or in Ultra-COMP® (Parker Hannifin) which is an injection moulding thermoplastic or an equivalent platic material. Preferably, the radius or radii of curvature of curved guiding channel 37 will not be lower than 25 mm for improving the rotation of the tubing 9 around its longitudinal axis.

[0028] The coil spring 35 sheathing the tubing 9 is able to reduce the friction torque between the tubing 9 and the guiding channel 37, thus maintaining the temperature of the tubing as well as that of the liquid (particularly the blood) flowing through it, lower than 38°, in order to prevent all blood injury (particularly blood hemolysis).

[0029] The coil spring is also able to rigidify the tubing 9 against the torque reaction in order to prevent any risk of complete or partial collapse of the conduits 4a, 5a, 6a, 7a inside the tubing 9.

[0030] The coil spring sheathed tubing according to the present invention is more particularly useful in the case of a liquid centrifuging apparatus disclosed in WO 00/61295, since such a coil spring sheathed tubing allows to substantially increase the rotational speed of the centrifuging rotor 1. The centrifugal force being proportional to the centrifugal radius and to the square of the rotational speed of the centrifugation cup 2, it may be observed that if the rotational speed of this cup 2 is doubled while its diameter is reduced by half the separation power remains unchanged. Accordingly, the present invention allows to obtain a very compact liquid centrifuging device having very low overall dimensions.

Claims

1. A device for centrifugation of a liquid comprising a stationary portion (10'), a processing chamber (3) rotatably mounted with respect to said stationary portion for rotation about a predetermined axis, a multi-chanel flexible tubing (9), one end of which being fixed with respect to said stationary portion substantially along said predetermined axis, with the other end of said flexible tubing being attached substantially on said axis in rotationally locked engagement to the processing chamber (3) and a supporting means (36) to prevent any substantial elongation of said tubing (9) due to the centrifugal forces to which it is submitted during rotation of said

processing chamber (3), **characterized in that** said multi-chanel flexible tubing (9) is sheathed with a coil spring (35) which is solid with it, from said one end to said other end of said flexible tubing (9), to prevent any direct contact between the latter and said supporting means (36).

2. A device according to claim 1, wherein said coil spring (35) is made in stainless steel.

3. A device according to any of preceding claims, wherein said coil spring (35) is glued around said tubing (9).

4. A device according to any of preceding claims, wherein the internal diameter of said coil spring (35) is approximately 2% larger than the external diameter of said tubing (9).

5. A device according to one of preceding claims, wherein the wire diameter of sail coil spring 35 is comprised between 0,1 to 0,6 mm.

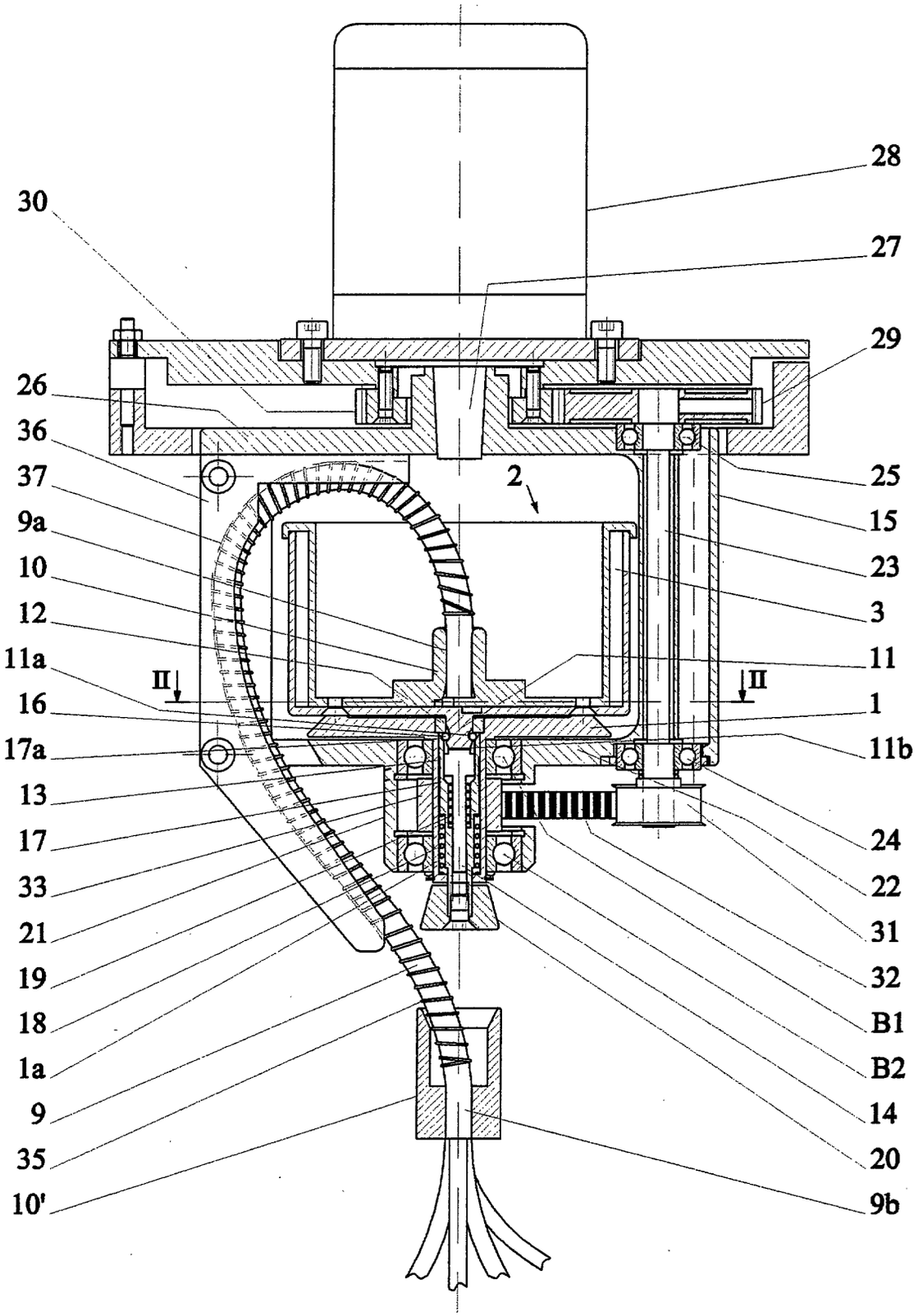
6. A device according to one of preceding claims, wherein the pitch between adjacent coils of said coil spring (35) is comprised between 2 to 5 mm.

7. A device according to one of preceding claims, wherein the winding direction of the coil spring (35) is the same than the rotation direction of said processing chamber (3).

8. A device according to one of claims 1, 3-7, wherein said coil spring (35) is made in a hard plastic material: hard PVC, PC or PMMA.

9. A device according to one of preceding claims, wherein said supporting means (36) has a curved shape, the radius of which is not lower than 25 mm.

10. A centrifugation member (2) configured for rotation about an axis for separating a liquid, especially blood, into two or more components, the liquid being delivered to, and the components being withdrawn from, the centrifugation member (2) by a single tubing (9) having a plurality of conduits (4a, 5a, 6a, 7a), the centrifugation member (2) having a cup shaped form, in the side wall in which is formed an annular separation chamber (3), and comprising a tubular housing (10) extending substantially coaxially to the annular chamber (3) for receiving an end of said multi-chanel flexible tubing (9), and a plurality of radially extending channels (4, 5, 6, 7) providing fluid communication between a respective conduit (4a, 5a, 6a, 7a) of said tubing (9) and said separation chamber (3), **characterized in that** the greater part of said multi-chanel flexible tubing (9) is sheathed with a coil spring (35) which is solid with it.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36
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2
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9a
15
10
23
12
3
11a
11
II
II
16
1
17a
11b
13
24
17
22
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19
B1
18
B2
1a
14
9
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Fig. 1

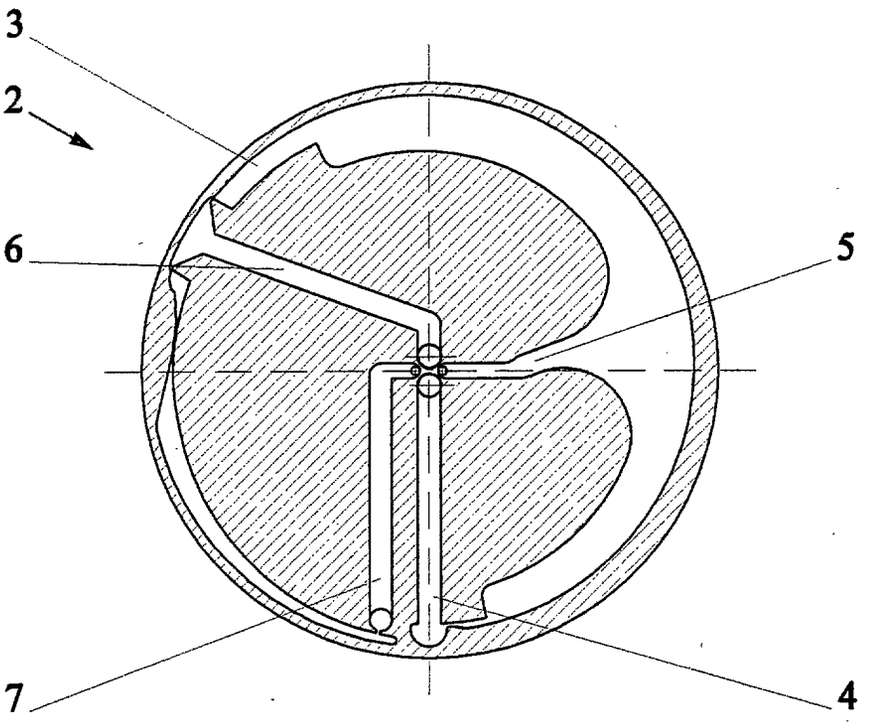

Fig. 2

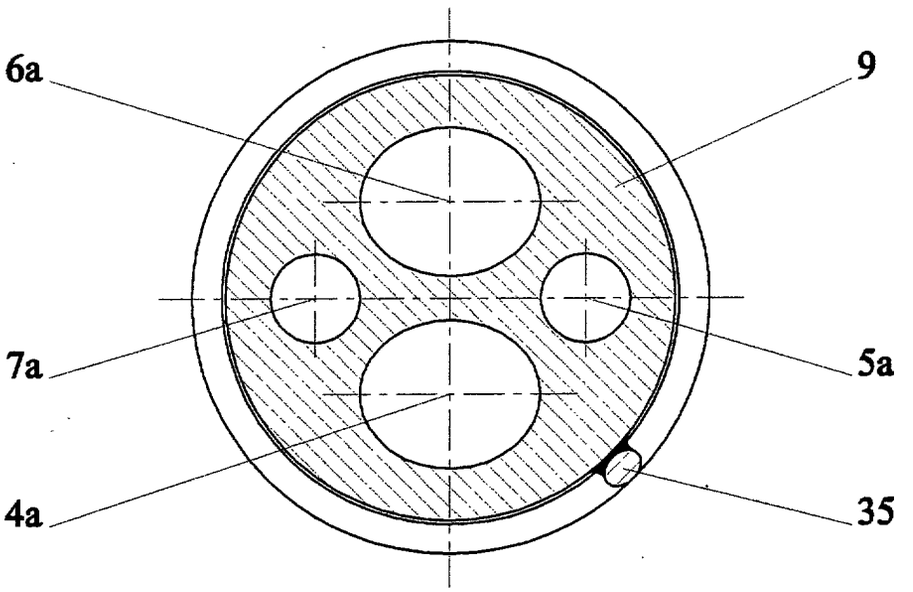

Fig. 3

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 02 40 5751

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TECHNICAL FIELDS SEARCHED (Int.Cl.7)

B04B
B01D
F16L

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
MUNICH	24 January 2003	Strodel, K-H

CATEGORY OF CITED DOCUMENTS

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