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(54) A semi-closed circuit, underwater breathing apparatus for medium and great depths

(57) A semi-closed circuit, underwater breathing apparatus for medium and great depths, comprising a source of breathing gas connected through a delivery pressure regulator to an expandible plenum chamber (4) having a pair of rigid walls (15,16); said expandible plenum chamber (4) being connected to a semi-closed circuit including a soda-lime filter (7) and an inspiration/exhalation mouthpiece for a diver; said expandible plenum chamber (4) being in mechanical connection with a discharge valve (11) towards the environment for discharging the surplus of breathing gas in the exhalation circuit as a consequence of an excessive expansion of said expandible plenum chamber caused by an increase of pressure of the breathing gas within said plenum chamber during normal breathing; there being also provided means with automatic control for the adjustment of the flow of breathing gas towards said plenum chamber as a function of the environment pressure (water head), and means for increasing the flow of breathing gas towards said plenum chamber for counteracting a possible collapsing of said expandible plenum chamber in the event of a fast increase of the environment pressure.

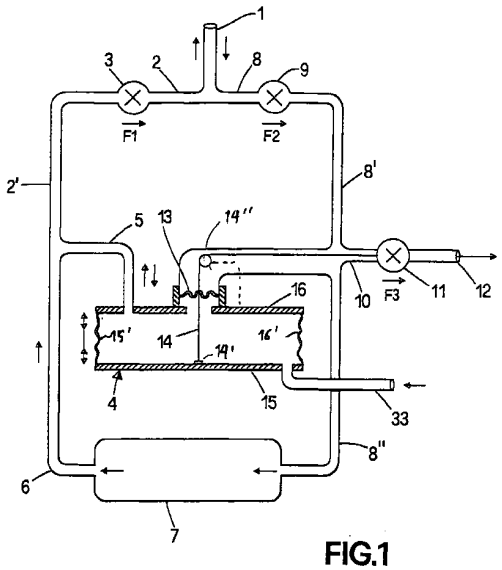

FIG.1

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Description

[0001] The present invention relates to a semi-closed circuit, underwater breathing apparatus for medium and great depths, for instance from zero up to 120-130 meters.

[0002] Semi-closed circuit underwater breathing apparatus for medium and great depths for divers including a source of breathing gas, a plenum chamber bag usually located on the back of the diver and a soda-lime filter, are known in the art.

[0003] The aim of the present invention is to provide an improved arrangement for a semi-closed circuit underwater breathing apparatus of the above mentioned kind.

[0004] According to the present invention there is provided a semi-closed circuit underwater breathing apparatus comprising a source of breathing gas connected through a delivery pressure regulator to an expandible plenum chamber having a pair of rigid walls; said plenum chamber being connected in a semi-closed circuit including a soda-lime filter and an inhalation/exhaust mouthpiece for the diver arranged in a known way; said expandible plenum chamber being in mechanical coupling with a discharge valve towards the environment for discharging a surplus of breathing gas in the exhaling circuit following an excessive expansion caused by an increase of the pressure of the breathing gas within said expandible plenum chamber during normal breathing; there being also provided means with an automatic control for the adjustment of the flow of breathing gas towards said plenum chamber as a function of the environment pressure (water-head), and manual control means associated to said automatic control means for increasing the flow of breathing gas towards said expandible plenum chamber for counteracting a possible "collapsing" of said expandible plenum chamber in the case of a fast increase of the environment pressure (water head) during a fast dive.

[0005] Still according to the present invention, there is provided a modified arrangement of the above structure wherein the manual control means are substituted with means for sensing the "collapsing" of said plenum chamber for increasing the flow of breathing gas so that the "collapse" is prevented and an acceptable expansion of said plenum chamber is maintained.

[0006] Other features, and characteristic of the present invention will become clear from a disclosure of preferred embodiments thereof given as a non limiting example, and with reference to the attached drawings, wherein:

figure 1 shows a general arrangement of a first embodiment of the breathing apparatus according to the present invention;
figure 2 shows a partial sectional view of the plenum chamber;
figure 3 and 4 show a rest and actuated condition, respectively, of the regulator of breathing gas with manual by-pass arrangement;
figures 5 and 6 show a modification of the general arrangement of the breathing apparatus according to the present invention;
figure 7 shows a partial sectional view of the expandible plenum chamber;
figure 8 shows an example of the mechanical structure that allows the parallel movement of the rigid walls of the expandible plenum chamber; and
figures 9 and 10 show details of the operation of a valve member associated to the plenum chamber.

[0007] With reference to the drawings and in particlar to figure 1, the breathing apparatus includes a portion of tubing 1 connected to a conventional mouthpiece (not shown). The portion of tubing 1 is connected by means of the portions 2, 8 to one-way valves 3, 9 that allow the passage of inspiration/exhalation gases in the direction of the arrows F1, F2, respectively.

[0008] The portions of tubing 2' branches into a conduit 5 that leads to the expandible plenum-chamber 4 and to a tubing portion 6 that leads to the outlet side of a conventional soda-lime filter 7.

[0009] Dowstream of the valve 9, there is located a conduit 8', 8" that leads to the inlet side of the soda-lime filter 7.

[0010] The portions of conduit 8', 8" are connected by means of a conduit 10 to a one-way valve 11 that allows the passage of surplus gas in the direction of the arrow F3 towards a conduit 12 that opens towards the environment (water).

[0011] The valve 11 is controlled, for example, by means of a flexible cable 14 that crosses sealingly a flexible sealing member 13 and is fastened to a wall 15 of the expandible plenum chamber 4 realized as a bellows 15', 16'.

[0012] The arrangement is such so that in the case of an excessive expansion of the expandible plenum chamber 4, a portion of the breathing gas is discharged towards the environment through the valve 11 actuated by the cable 14, in order to maintain the correct volume of the expandible plenum chamber 4.

[0013] The operation of the flexible cable 14 is controlled by the combined action of the walls 15, 16 of the expandible plenum-chamber 4. As it can be seen from figure 1, one end of cable 14 is fastened in 14' to the wall 15, and the part of the cable 14 extending beyond the sealing member passes over a pulley 14" fastened with means not shown to the wall 16 of the plenum chamber 4.

[0014] By means of a conduit 33 there arrives into the expandible plenum chamber 4 breathing gas, as it will be shown into detail with reference to figures 3 and 4.

[0015] In figure 2 there is shown by way of example a detail of the expandible plenum chamber 4.

[0016] As one can see in figure 2, the plenum chamber 4 is defined by two rigid walls or shells 15, 16 and by

bellows walls 15', 16'.

[0017] By means of a mechanism provided with hinges 19, 20 and a stabilizing bar 18 a structure is realized, by means of which the rigid walls 15, 16 can move substantially parallel each other. The structure 18, 19, 20 is duplicated in order to constitute a parallelogram structure well known per se.

[0018] With reference now to figures 3 and 4 there will be disclosed the "by-pass" device in the conditions normal and of compensation, respectively, for counteracting the "collapsing" of the above described expandible plenum chamber 4, in the case of a fast diving (fast increase of the environment pressure caused by the water head above the diver).

[0019] The by-pass device includes a body 40 whereon a shaft 41 is arranged, provided with a push-button 42 for a manual actuation, the purpose of which will be discussed below. Between the body 40 and the shaft 41 there is provided a membrane 43 for separating the environment (water) and the breathing gas at the interior of the body 40. The shaft 41 extends in 44 into the chamber 45 for actuating a pin or conical shutter 46 against a counter-acting spring 47 for controlling the inflow of breathing gas introduced by the connection piece 48 connected to a conventional pressure regulator fed by a container of pressurized breathing gas, such as a cylinder.

[0020] Between the connection piece 48 and the chamber upstream of the pin 46, there is provided a conduit 49 that leads to one or several selectable flow-restricting nozzles 50 for restricting the flow of breathing gas (only one shown).

[0021] The flow-restricting nozzles 50 are connected with a conduit 51 to the connection piece 33 corresponding to the connection piece 33 shown in figures 1 and 2.

[0022] The connection piece 33 is connected to the conduit 53 that opens on the gas side of the membrane 43.

[0023] The cooperation of the membrane 43 between the environment pressure (water-head) applied on a side thereof by the opening 54 and the pressure determined by the flow-restriction nozzle 53 provides for the stabilization of the equilibrium conditions and pressure within the breathing plenum chamber for the diver as it is well known to a person skilled in the art.

[0024] In the case of a fast dive, the increase of the environment pressure (water) may lead to the "collapse" of the plenum chamber 4. In this case, as it is shown in figure 4, the diver by pushing the push button 42 performs a forced by-pass of the flow-restriction nozzle or nozzles 50 restoring the correct average expansion of the expandible plenum chamber 4.

[0025] In the event of an excessive expansion of the plenum chamber 4, the valve 11 of figure 1 will operate, as above discussed, restoring the correct situation.

[0026] Now, with reference to figures 5 to 10 a second embodiment of the underwater breathing apparatus according to the present invention will be disclosed.

[0027] With reference to figure 5, the modified embodiment of the breathing apparatus includes a part 101 to which a conventional mouthpiece (not shown) is connected. The part 101 cooperates with one-way valves 102 and 110 that allow the passage of breathing gas during breathing in the direction of the arrows F101 and F110.

[0028] Downstream of the unidirectional valve 102 there is provided a conduit 103 that branches in 103' and 104, respectively, that allow the breathing gas to reach a conventional soda-lime filter 105, and in the condition of complete filling of the circuit, the breathing gas reaches through the conduit 104 a one-way valve 119 and a discharge opening 106 that in the condition of maximum expansion of the plenum chamber 109 is opened by the sealing member 122 and that operates as a shutter for the discharge opening 106, allowing the elimination towards the environment (water) of the surplus breathing gas through the outlet 120.

[0029] More details about the discharge operation for the surplus breathing gas will be discussed below.

[0030] The outlet side of the soda-lime filter 105 is connected to a conduit 107 that is branched in 108, 107' that allows the breathing gas to arrive both to the plenum chamber 109 and to the one-way valve 110 cooperating with the part 101 associated to the mouthpiece (not shown).

[0031] It should be noted that in the conduit 108, the breathing gas has a bi-directional flow as indicated by arrows F103, F104 according to the inhalation/exhalation action of the lungs of the diver (see figures 5 and 6).

[0032] The continuous-flow feed of breathing gas that arrives to the plenum chamber 109 is provided by the conduit 111 that is connected to a flow-restriction nozzle located downstream of a pressure regulator, not shown in the drawings because well known to a person skilled in the art.

[0033] The flow-rate of breathing gas will be adjusted to allow the correct uptake of oxygen for the needs of the diver.

[0034] Downstream of the conduit 112 that is connected upstream of the pressure regulator, by-passing the flow-restriction nozzle, (not shown) there is connected a valve 113 for the compensation of the volume of the plenum chamber 109. The valve 113 is actuated by a push-button member 114, that in turn is operated by one of the rigid walls of the plenum chamber 109: in the embodiment shown in figures 6 and 7, by the rigid wall 116.

[0035] If a reduction of the volume of the plenum chamber 109 occurs, and this may happen during a descent of the diver towards a greater depth (increase of the environment pressure), the plenum chamber 109 would be subject to a collapse, preventing a normal volumetric breathing by the diver.

[0036] The collapse of the plenum chamber 109 causes (see figure 6) the actuation of the push-button

114 by the wall 116 of the plenum chamber, opening the volume compensation valve 113 that through the outlet 115 feeds breathing gas into the plenum chamber 109, restoring almost immediately the correct volume of the plenum chamber 109, and the correct situation of the whole breathing circuit.

[0037] A situation opposite to the one just discussed occurs in the case of an excessive expansion of the plenum chamber 109. In a manner similar to what has been discussed with reference to the first embodiment, the rigid walls 116, 117 of the plenum chamber 109 become more distant each-other, putting under tension the automatic-control flexible cable 121 (see figures 5 and 9) that is fastened at a first end to the rigid wall 116 and at a second end to the flexible membrane 122, thus compressing he helical spring 133 and causing the discharge of surplus breathing gas through the discharge opening 106, directly towards the environment (water).

[0038] A partial collapse of the plenum chamber 109 causes a decrease of the tension on the flexible cable 121 causing the closure of the passage 106.

[0039] The flexible membrane 122/shutter 106 is provided for a double purpose, firstly for avoiding that the breathed gas, i.e. the gas that is produced by the diver during exhaling, may arrive directly to the plenum chamber 109, by-passing the soda-lime filter 105 (see figures 5 and 6), and secondly, to open and to close the opening 120 at the right time.

[0040] In figures 5 and 9 it can be clearly seen that, once the circuit and the plenum chamber 109 are filled, the only possible exit for the breathed gas is the opening 106 located downstream of the conduit 104, since the flexible membrane 122 prevents the passage towards the plenum chamber 109.

[0041] It should be noted that the part of breathed gas that comes out of the discharge opening 106, without passing through the soda-lime filter 105 is the part of breathing gas more saturated with CO_2 and more depleted of O_2. This allows a greater life of the soda-lime filter and a smaller decrease in percentage of the oxygen in the breathing gas, that by mixing in the plenum chamber 109 with a "fresh" breathing gas, is then again breathed.

[0042] With reference now to figures 7 and 8, it can be seen that the expandible plenum chamber 109 comprises two rigid walls 116, 117 and a bellows 118.

[0043] To the rigid walls 116, 117 a movable parallelogram structure is fastened, that is linked to the rigid walls 116 and 117 in 131 and 132, and movably in 125 in cooperation with the slot 128.

[0044] This structure is also hinged in 133 between the stabilizing bar 126 and the half-bar 127. This structure is duplicated by means of the cross-bars 129 and 130 so as to constitute an articulated parallelogram as one can see in figure 8.

[0045] The structure above disclosed allows a parallel motion of the rigid walls 116, 117.

[0046] The maximum expansion of the plenum chamber 109 is controlled both by the bellows 118 and by the flexible cable 121.

[0047] An excessive expansion of the plenum chamber 109 is prevented by the operation of the membrane 122 according to the operative mechanism above discussed.

[0048] According to the invention, the plenum chamber 109 is preferably arranged over the breast of the diver in correspondence of the "center of gravity" of the lungs, thus avoiding in such way the pressure gradient that usually occurs when an expandible plenum chamber is arranged on the back of a diver.

[0049] This is advantageous since usually a diver operates in vertical position or face-down position.

[0050] Moreover, in this way, the diver can keep under control by sight or with his hands the degree of expansion of the expandible plenum chamber. This would be impossible if the plenum chamber were located on the back.

Claims

1. A semi-closed circuit, underwater breathing apparatus for medium and great depths, comprising a source of breathing gas connected through a delivery pressure regulator to an expandible plenum chamber having a pair of rigid walls; said expandible plenum chamber being connected to a semi-closed circuit including a soda-lime filter and an inspiration/exhalation mouthpiece for a diver; said expandible plenum chamber being in mechanical connection with a discharge valve towards the environment for discharging the surplus of breathing gas in the exhalation circuit as a consequence of an excessive expansion of said expandible plenum chamber caused by an increase of pressure of the breathing gas within said plenum chamber during normal breathing; there being also provided means with automatic control for the adjustment of the flow of breathing gas towards said plenum chamber as a function of the environment pressure (water head), and means for increasing the flow of breathing gas towards said plenum chamber for counteracting a possible collapsing of said expandible plenum chamber in the event of a fast increase of the environment pressure.

2. A semi-closed circuit underwater breathing apparatus according to claim 1, wherein manually controlled valve means are provided for increasing the flow of breathing gas towards said plenum chamber for counteracting said possible collapse of said plenum chamber.

3. A semi-closed circuit underwater breathing apparatus according to claim 1, wherein automatic valve means are provided for increasing the flow of breathing gas towards said plenum chamber for

counteracting said possible collapse of said plenum chamber.

4. A semi-closed circuit underwater breathing apparatus according to claim 3 wherein said automatic valve means comprise a push-button valve actuated by a wall of said expandible plenum chamber in the event of a collapse thereof.

5. A semi-closed circuit underwater breathing apparatus according to one or more of the preceding claims wherein said expandible plenum chamber comprises a pair of rigid walls coupled each other by means of a bellows arrangement.

6. A semi-closed circuit underwater breathing apparatus according to claim 5 wherein the rigid walls of said expandible plenum chamber are coupled each other also by means of an arrangement of hinges and coupling bars constituting an articulated parallelogram whereby the motion of said rigid walls occurs in a parallel fashion.

7. A semi-closed circuit underwater breathing apparatus according to one or more of the preceding claims wherein means are provided for preventing an excessive expansion of said plenum chamber, said means comprising a flexible member fastened to a first of said rigid walls and to a membrane element arranged for discharging in the environment surplus breathing gas causing said excessive expansion of the plenum chamber.

8. A semi-closed circuit underwater breathing apparatus according to one or more of the preceding claims wherein one-way valve means are provided for discharging excess breathing gas that normally accumulates in the breathing circuit.

9. A semi-closed circuit underwater breathing apparatus according to one or more of the preceding claims arranged for being located on the breast of a diver substantially in correspondence with the "center of gravity" of the lungs.

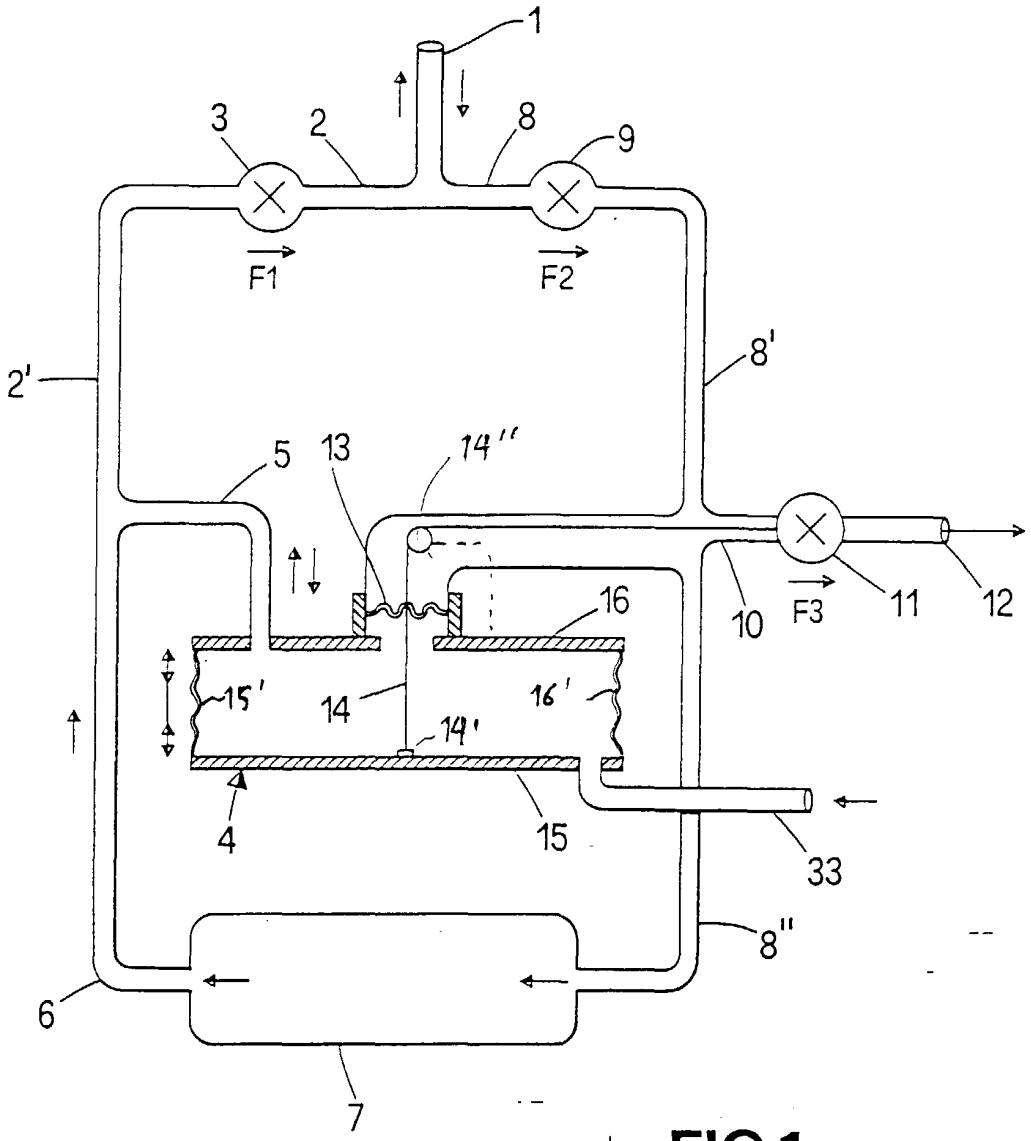

FIG.1

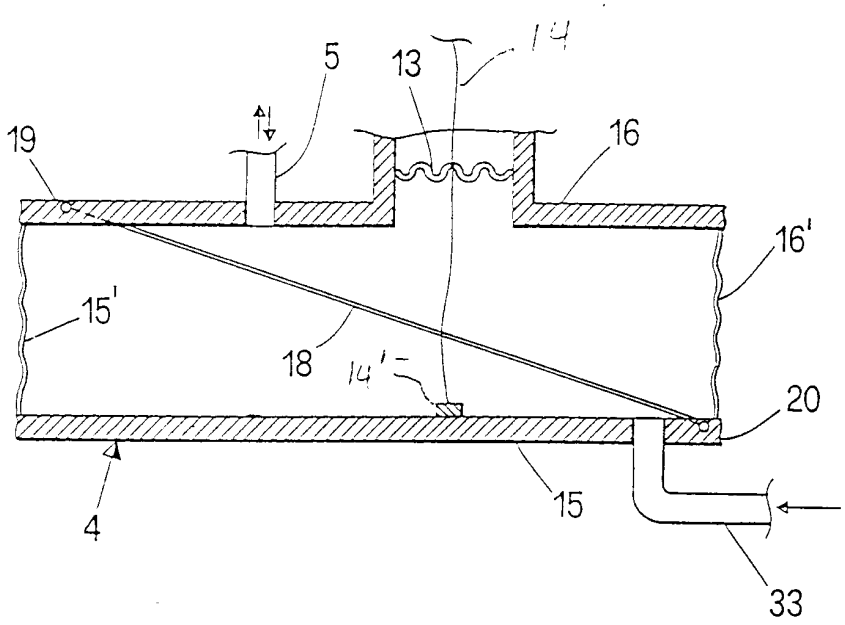

FIG.2

FIG.3

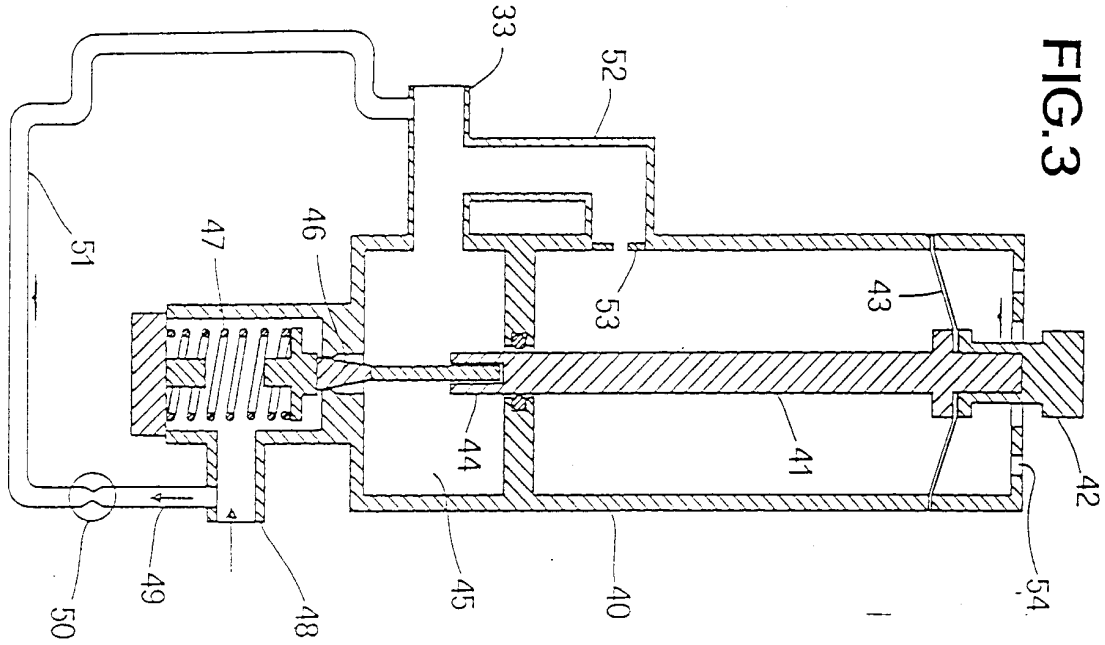
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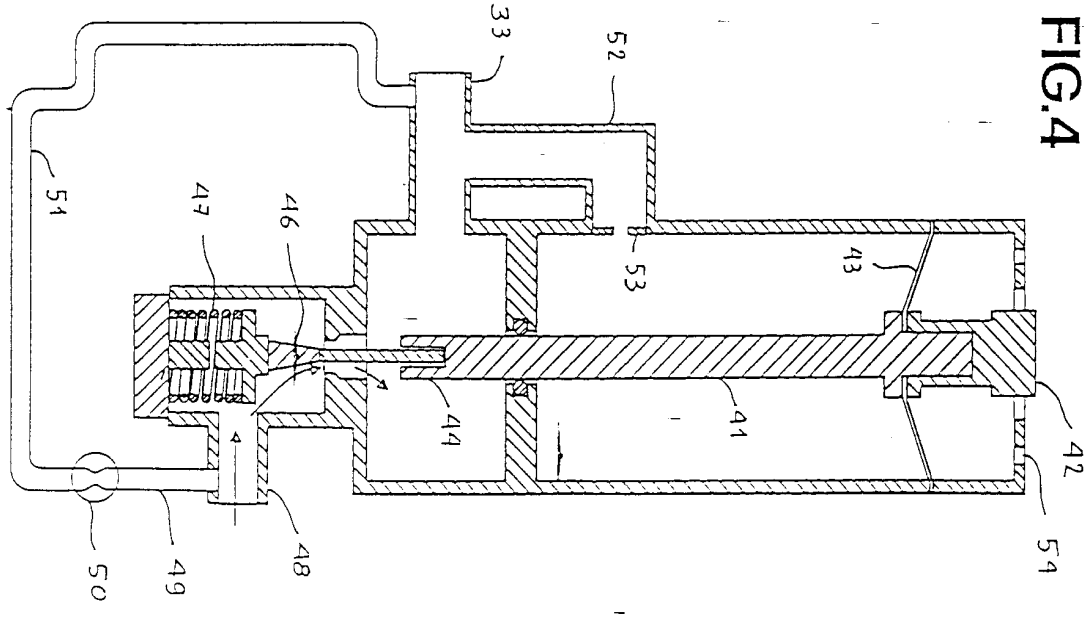
FIG.4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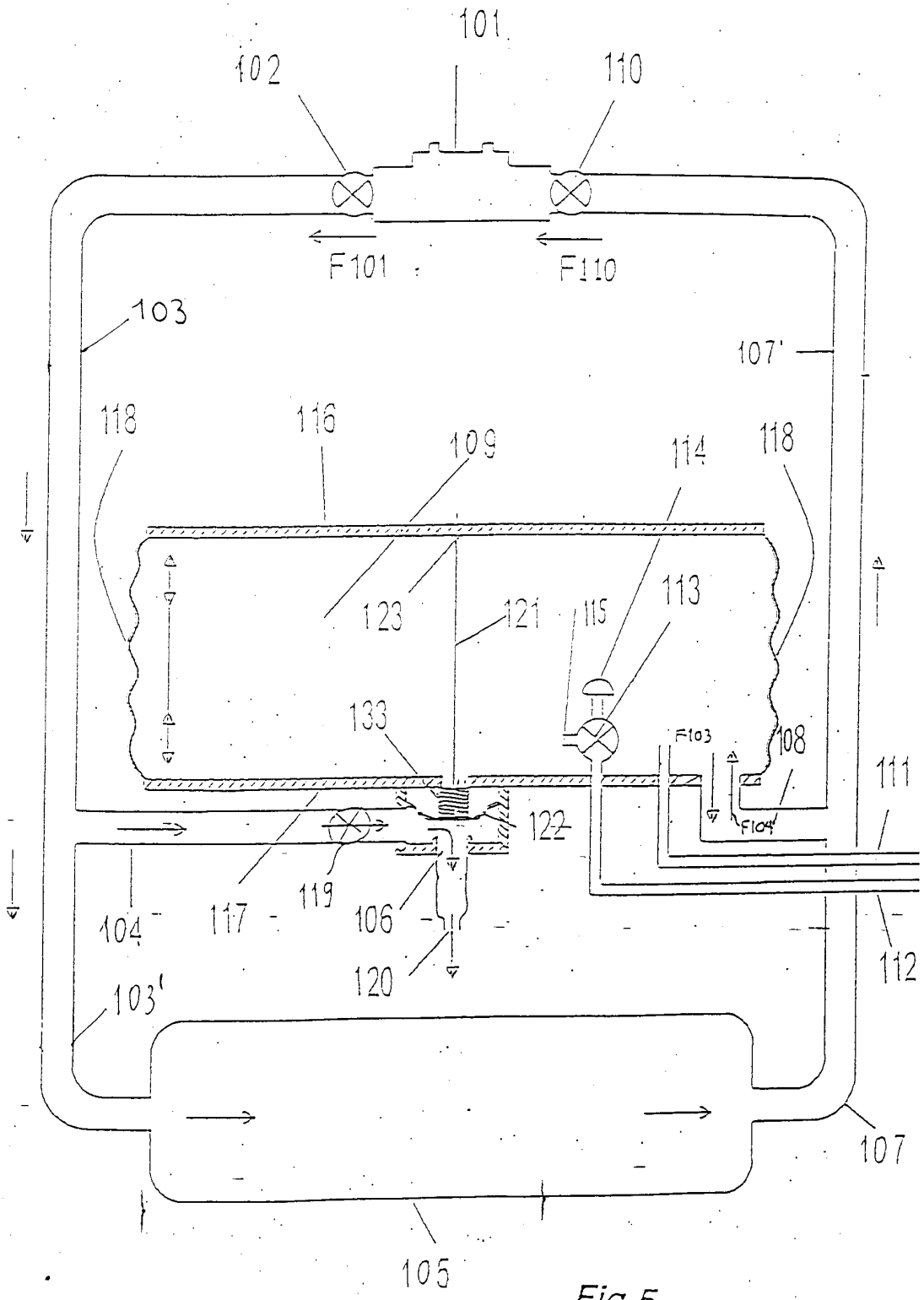
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Fig.5

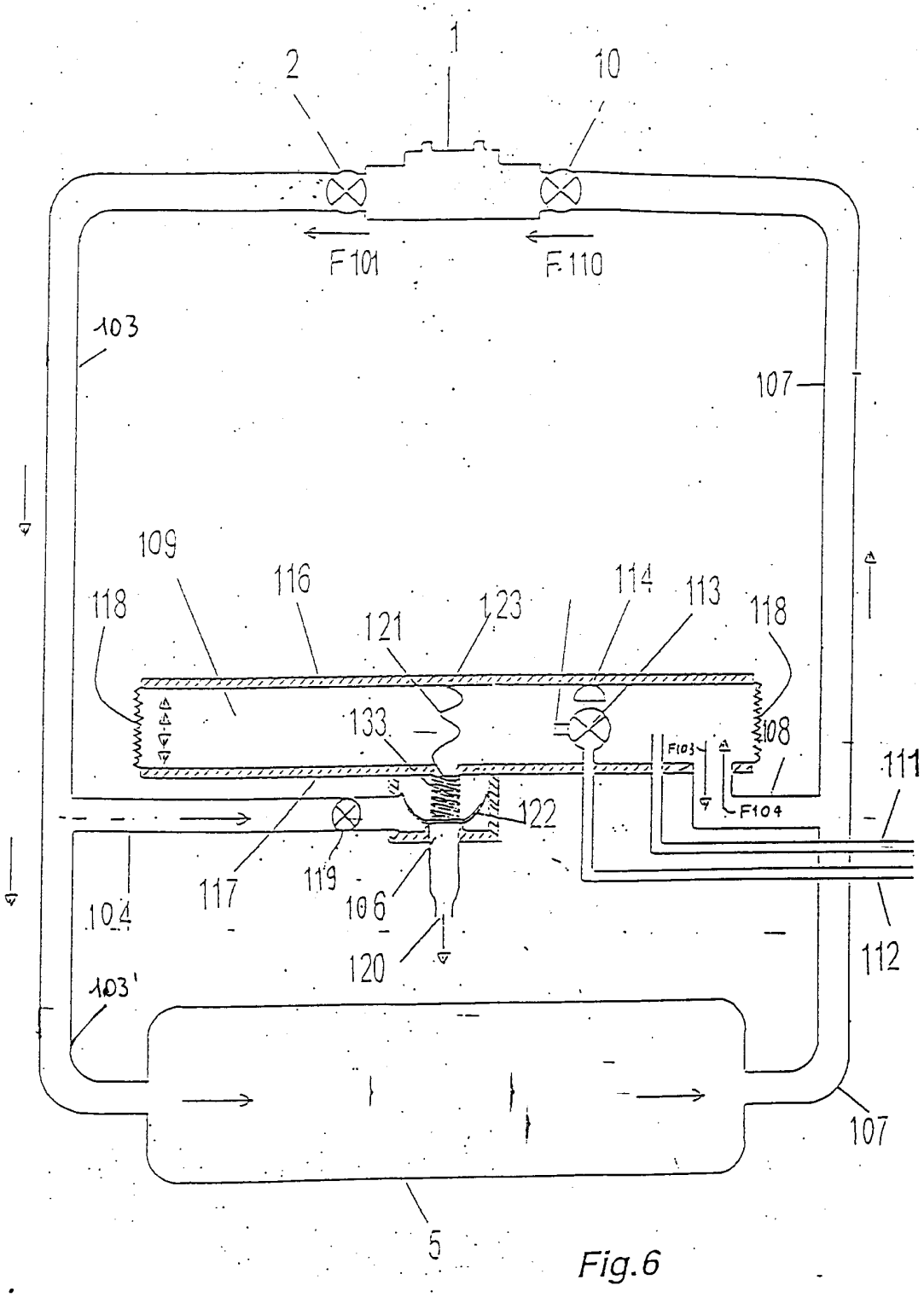
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Fig.6

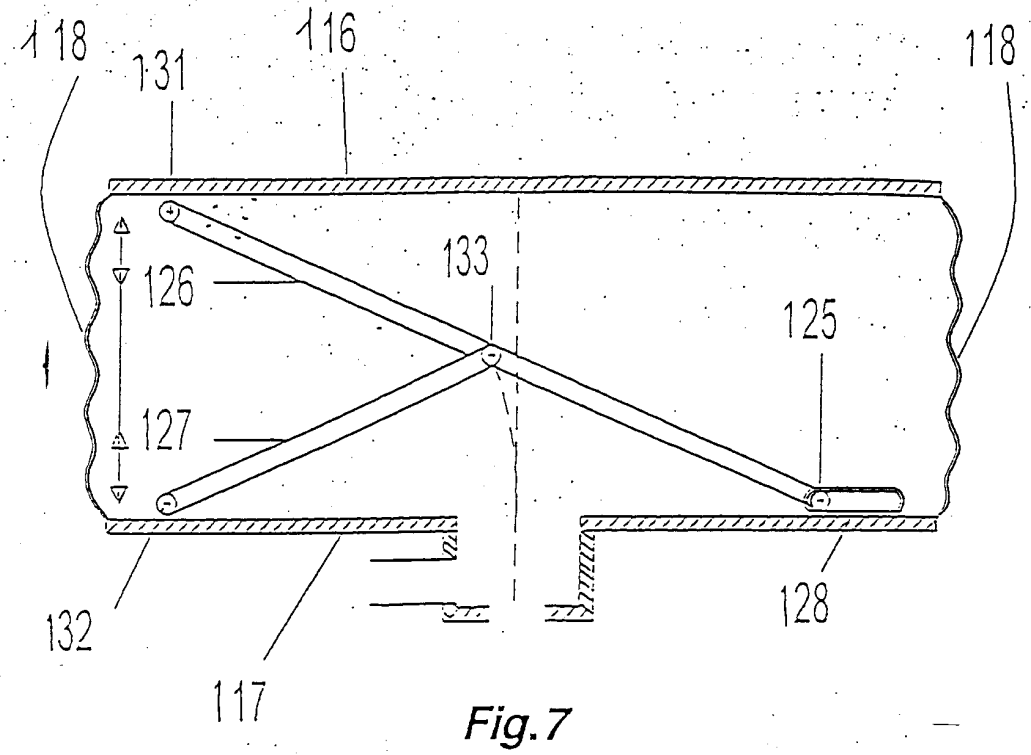
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Fig.7

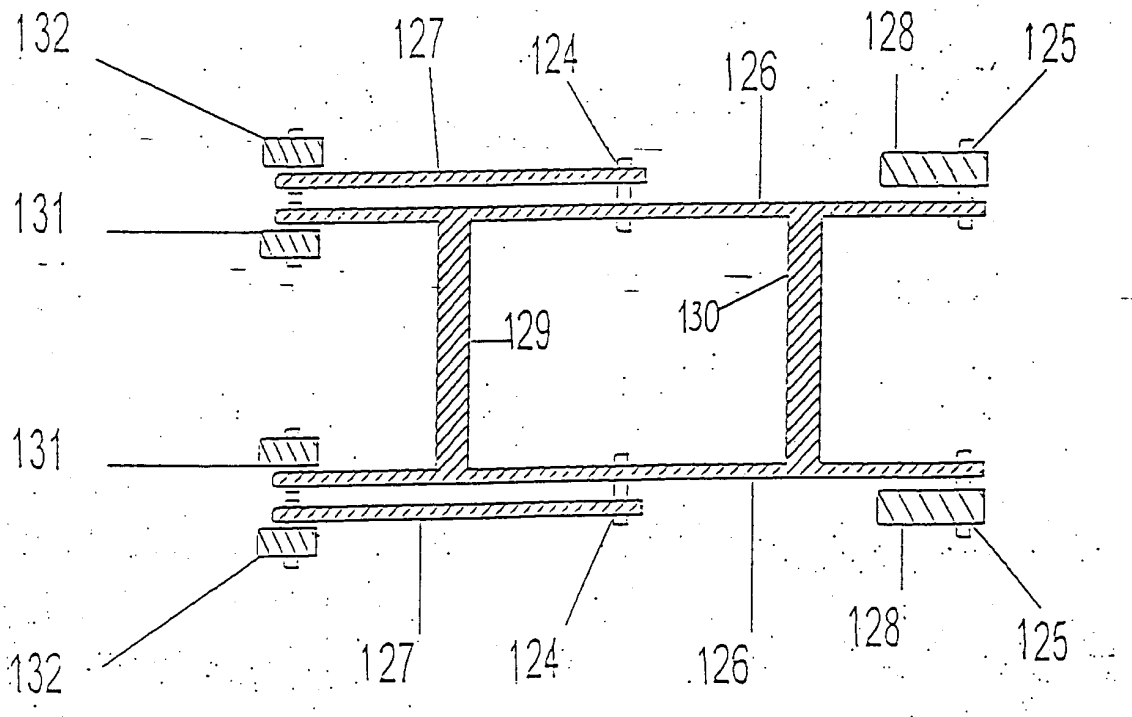
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Fig.8

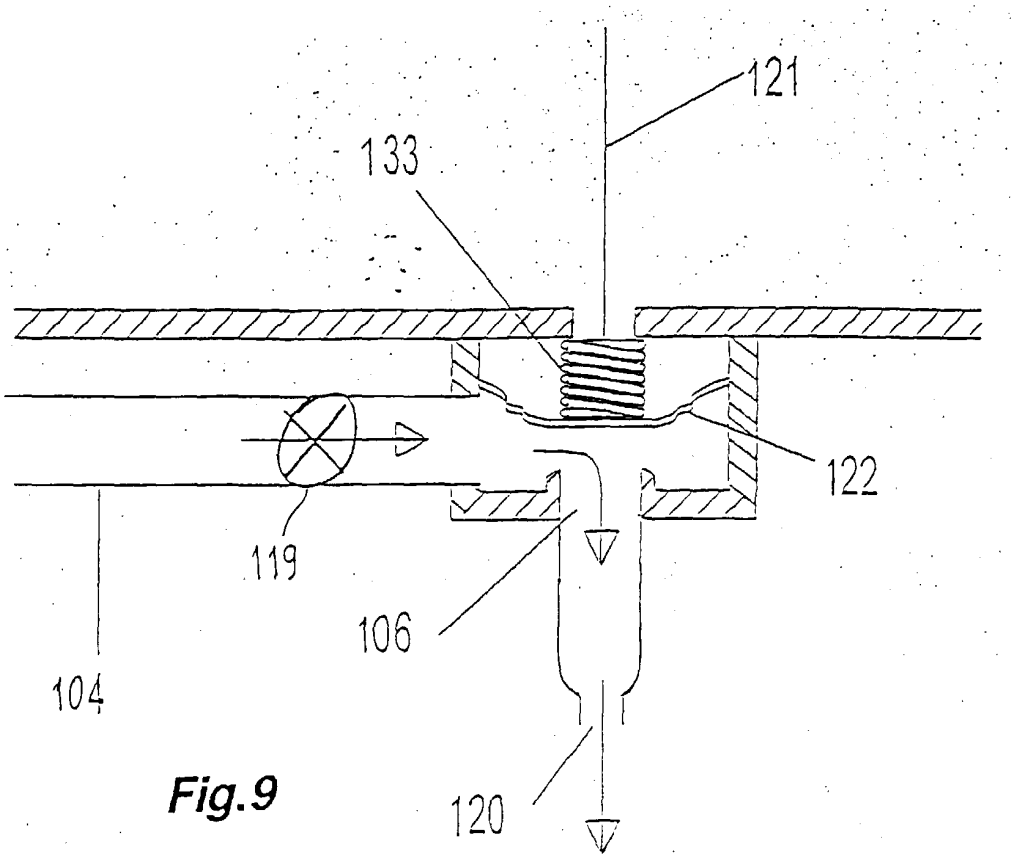

Fig.9

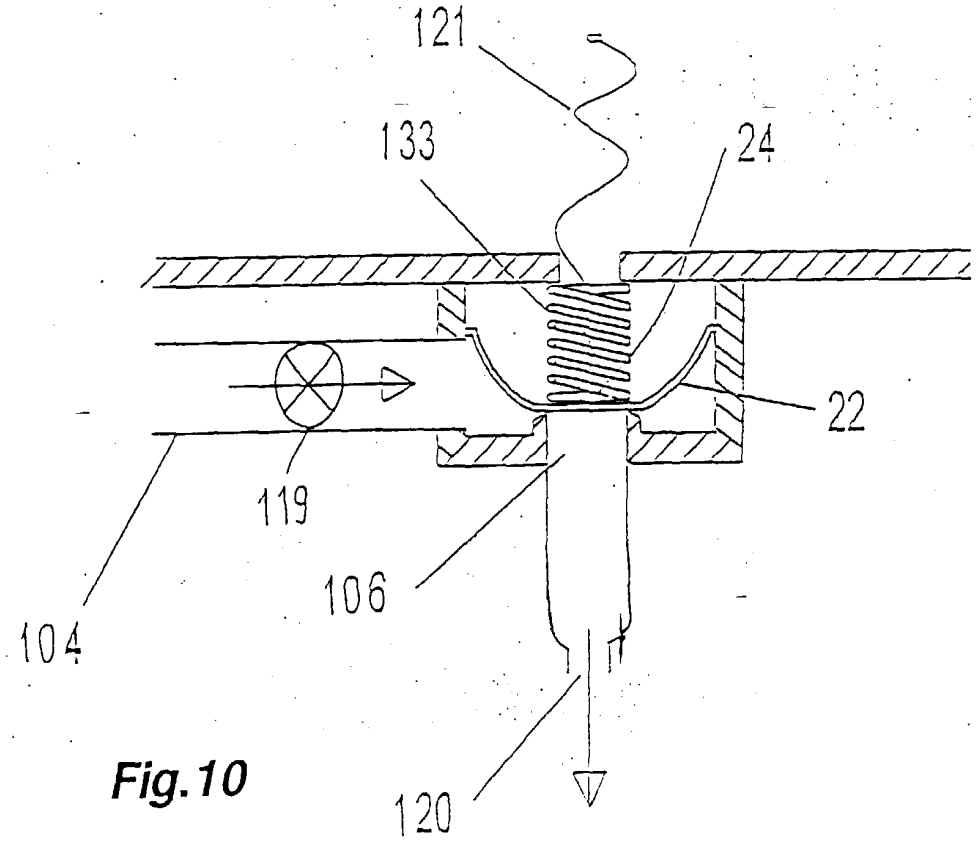

Fig.10

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EUROPEAN SEARCH REPORT

Application Number
EP 97 83 0577

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
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Y A	FR 1 550 305 A (FENZY) * page 2, right-hand column, line 45 - line 55; figure 2 * ---	4,9 5	
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A	FR 1 479 578 A (SHELL INTERNATIONALE RESEARCH MAATSCHAPPIJ) * page 4, right-hand column, last paragraph; figure 2 * ---	1	TECHNICAL FIELDS SEARCHED (Int.Cl.6) B63C
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	7 April 1998	DE SENA, A

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