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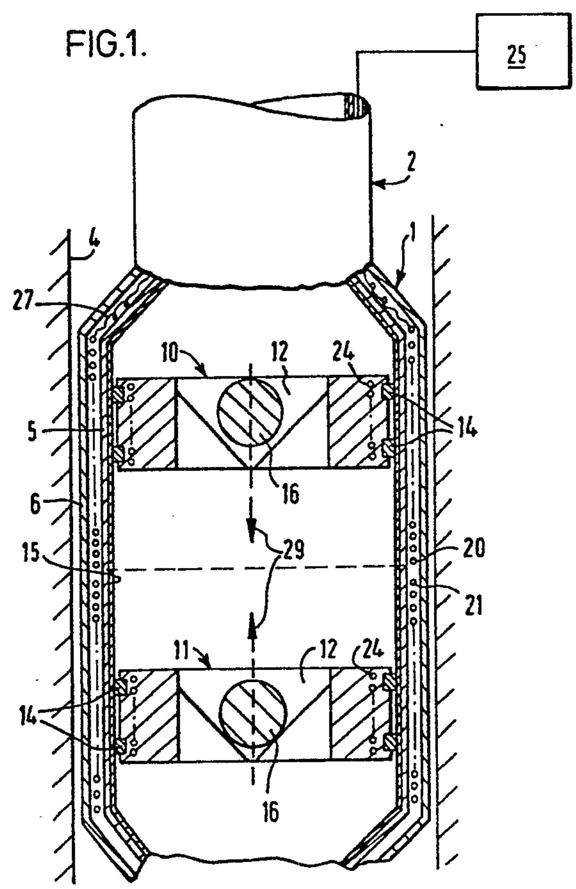
(54) **Reciprocating pump unit.**

(57) Pump units with reciprocably movable pistons driven by linear electric motors move substantially equal volumes of fluid on each stroke. Two pistons (10,11) can be moved alternately towards and away from each other, or a piston assembly comprising a piston (60;85) is reciprocated in a cylinder (61;82) together with a discharge tube (56;99) extending from the piston into a discharge duct (75;102).

FIG.1.



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RECIPROCATING PUMP UNIT

The invention relates to a pump unit of the kind in which a pumping action is effected by reciprocating movement of a piston or pump element.

Positive displacement pumps of this kind offer many advantages, for example simplicity and reliable operation, particularly for relatively small pumping capacities, but they have the disadvantage that the movement of the fluid being pumped is not continuous. A pulsating flow results from the successive repeated pumping strokes of the pump element.

It would therefore be advantageous to provide a pump unit capable of providing an even or relatively even flow of the pumped fluid. Such regulated flow is of particular advantage at the suction side of oil extraction pumps where it creates good extraction conditions. It is moreover advantageous to drive reciprocating pump units by linear electric motors and such motors are best employed with an even flow.

The present invention accordingly provides a pump unit having an inlet or suction space,a pump space, a discharge space, and piston means reciprocably driven so as to move a fluid to be pumped into the discharge space during both a first stroke, in which the fluid is expelled from the pump space, and a return stroke in which the fluid is moved from the inlet space into the pump space.

Pump units of the invention can be readily arranged to move substantially equal amounts of the fluid into the discharge space during each stroke, so as to achieve an even pumped discharge and the piston means are conveniently driven by linear electric motors which can be arranged to be substantially equally loaded during each stroke.

The invention can thus provide a pump unit having two reciprocating piston elements located in series in the pumping direction, the piston elements being associated with non-return valves and being reciprocated in opposed phase, so as to be effective alternately. The piston elements can conveniently have one or more passages therethrough fitted with appropriately orientated non-return valves.

Thus, upstream and downstream piston elements are cyclically moved towards and away from each other. As the piston elements move apart, the downstream element expels the fluid being pumped to the outlet or discharge and draws fluid in through the non-return valve of the upstream element, which has no pumping function until the piston elements reverse direction and move towards each other. It is then the upstream piston element which functions to draw in fluid to the inlet space and to expel it through the downstream non-return valve.

The invention can thus also provide a pump unit comprising a cylinder having a piston movable to draw a fluid to be pumped into the cylinder from an inlet and to discharge the fluid therefrom into a discharge space by way of a hollow piston rod extending from the piston outwardly of the cylinder into the discharge space. As the piston draws fluid into the cylinder the corresponding movement of the piston rod carries the fluid in its interior into the discharge space, and as the piston moves in the reverse direction the fluid in the pump space is expelled into the discharge space through the piston rod.

The piston means is conveniently driven electrically, as by a linear electric motor, the operation of which can be either synchronous or asynchronous. Where the piston means comprises two piston elements, there can move within a common pump casing, and for each pump element, a winding in the casing wall constitutes the stator of the linear motor and the piston itself constitutes the so-called rotor. The two motors are powered so that the phase sequence provides fields travelling in opposite directions. Where the piston means comprises a single piston and piston rod assembly, this can carry a surrounding sleeve constituting the rotor which is itself surrounded by a stator winding.

The invention is further described below, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a schematic sectional side view of a first pump unit embodying the present invention; and

Figures 2 and 3 are like views of a second and a third pump unit embodying the present invention, respectively.

The pump unit 1 illustrated in Figure 1 is intended as an oil lift pump, and is shown as being carried at the lower end of the tubular pipe stack 2 within a drill hole 4. The pump unit 1 comprises a pump casing comprising concentric cylindrical inner and outer shells 5 and 6, of which the interior of the inner shell defines a pumping chamber. The lower end of the chamber communicates with the oil to be pumped, and the upper end communicates with the interior of the pipe stack 2 which serves as an oil delivery pipe.

Within the inner casing shell 5 there are received, one above the other, two like plunger elements or pistons 10,11 of annular form with central passageways 12. The piston outer peripheries are provided with sealing/bearing elements 14 so as to make a sliding seal with the inner face 15 of the inner shell 5 which is of non-magnetic material. The passageway 12 within each piston 10,11 is closed by a non-return valve 16. Both non-return valves 16 are arranged so as to permit oil flow upwardly and to prevent oil flow in the downward direction. Oil can thus flow upwardly through the piston 11 into a pump chamber or region between the pistons, and through the piston 10 into a discharge chamber or region above it and communicating with the pipe stack interior.

Between the inner and outer pump housing shells, there are accommodated upper and lower stator windings 20,21. The upper stator winding 20 surrounds the upper piston 10 and forms with it a linear electric motor, of which the piston constitutes the so-called "rotor" or driven portion. Similarly, the lower stator winding 21 surrounds the lower piston 11 to constitute a second, independently controllable, linear electric motor, with the lower piston as its rotor. If required, each of the pistons 10,11 can each be provided with a rotor winding 24 adjacent its outer periphery. The stator windings 20,21 each extend over about one half of the axial length of the pump casing interior, so each piston is capable of reciprocating movement axially of the casing between the axial centre and a respective end of the pump casing.

Three-phase, frequency controlled, electric power is carried to the stator windings 20,21 from control and supply circuitry 25 at the upper end of the pipe stack 2, by conductor means 27 extending along it. Preferably such conductor means comprises three concentric tubular conductors with insulation between them. The concentric conductor tubing can be received between outer pipe stack tubing and an interior liner containing the crude oil flow, with spacing to accommodate flow or circulation of protective or barrier fluid, which can extend through the pump casing between the inner and outer shells. Particulars of suitable concentric conductor and protective fluid flow arrangements appear from EP-A-0 063 444 which is incorporated herein by reference.

In operation, the two linear electric motors and are operated so that the upper and lower pistons 10,11 move in opposite directions. Referring to an initial situation in which the upper or downstream piston 10 is at its uppermost position and the lower or upstream piston 11 is at its lowermost position within the pump casing, the linear electric motors are energised so that the lower piston 11 is raised and the upper piston 10 lowered, until the pistons come into adjacency at the axial centre of the pump casing. During this movement, indicated by the arrows 29, the non-return valve 16 of the lower piston 11 will be closed by the pressure of the oil between the pistons, but the upper non-return valve will open. The lower piston 11 is thus operating to draw in fresh oil from below and at the same time to expel oil upwardly through the upper piston 10, which is at this time passive or inoperative, into the discharge region above it and thus into the pipe stack 2.

Directly the pistons 10,11 have reached the end of the travel towards each other, the phase sequence of the supply current is altered so that the linear electric motors operate to reverse the directions of travel of the pistons. These consequently move apart. The upward movement of the upper piston 11 causes closure of its non-return valve so the piston moves the oil above it in the discharge region upwardly into the pipe stack 2, whilst oil is drawn up below the upper piston by flowing through the lower non-return valve into the enlarging pump chamber between the pistons. At the end of this stroke, the pistons 10,11 have again reached the initial position in which they have their greatest separation.

The pump units illustrated in Figures 2 and 3 each incorporate a single linear electric motor which can be constructed, and operated by appropriate supply and control circuitry, similarly to the motors of the pump unit of Figure 1.

The pump unit of Figure 2 can be employed for oil extraction similarly to that of Figure 1. It comprises a circular cylindrical outer housing 51 closed at its lower end, which is submerged in use in the oil to be pumped, by an end wall 52. Somewhat above the end wall 52, the housing 51 internally supports an annular stator winding 54 of a linear electric motor, of which the driven portion comprises a concentric sleeve 55. The sleeve 54 is guided for reciprocation in the housing 51 by a concentric hollow pump shaft 56 to which it is connected by a radial web 57 positioned midway along the sleeve. At its lower end, the hollow pump shaft 56 carries a piston 60 slidably received within a cylinder comprising inner and outer walls 61 and 62 extending concentrically upwardly from the end wall 52. An inlet or suction aperture 64 in the end wall 52 communicates an inlet region containing the oil to be pumped with a pump chamber 65 defined by the cylinder inner wall 61, the end wall, and the piston 60, by way of a non-return valve 66. A second non-return valve 67 in an aperture through the piston 60 communicates the pump chamber 65 with the interior of the hollow discharge tube or pump shaft 56.

An equalization chamber 70 is defined by the cylinder inner wall 61, the upper side of the piston 60, and an annular end wall 71, through which the pump shaft 56 is sealingly guided. The chamber 70 communicates with the oil to be pumped by the space between the walls 61 and 62 and passages 72 in the end wall 52. A discharge space 75 is defined by a discharge duct 76 which is concentrically fixed within the housing 51 and of which the lower end is closed by an annular wall 77. The upper end of the pump shaft 56 projects into the discharge chamber 75 through the annular wall 77 in which the pump shaft is slidingly guided.

The operation of the pump unit of Figure 2 is as follows.

On appropriate energisation of the stator winding 54, the unitary piston structure constituted by the sleeve 55, the web 57 and the hollow pump shaft 56, is moved upwardly, so that oil is drawn into the pump chamber 65 through the non-return valve 66. Oil within the equalization chamber 70 is discharged into the suction region at the lower end of the housing through the passages 72, and the upper end of the pump shaft protrudes further into the discharge chamber 75.

When the piston 60 has reached the upper end of the pump cylinder, this direction of movement is reversed by changing the energization of the winding 54, so that the oil that has been drawn into the pump chamber 65 enters the interior of the pump shaft 56 through the non-return valve 67, the non-return valve 64 being closed. At the same time, oil is drawn in to the equalization chamber 70 through the passages 72. When the downward stroke has been completed, the cycle recommences with another upward stroke of the piston.

The pump unit of Figure 2 achieves an even flow of the pumped oil into the discharge chamber 75 in that the volume of the pump shaft received in the discharge chamber at the end of the upward stroke is at least approximately half the volume of the pump chamber 65. The volume of oil flowing into the discharge chamber 75 on a downward stroke equals the volume of the pump chamber 65, as swept by the piston 60, minus the volume of the pump shaft that is withdrawn from the discharge chamber, that is half the pump chamber volume. On upward movement of the piston 60, the pump shaft 56 effectively displaces its volume of oil within the discharge chamber 75, so that the resultant change in the discharge chamber is half the pump chamber volume on each of the upward and downward strokes. The drive motor is thus loaded in both directions.

Oil flow into and out of the pump chamber 65 is of course equalised by the displacement of the oil from and into the equalization chamber 70.

The pump unit of Figure 3 operates in a similar way to the unit of Figure 2 but has the pump inlet and outlet at the same end. An inlet duct or pipe 81 extends from a body of the fluid to be pumped to a straight portion which provides a cylinder portion 82 and a housing portion 84 for a linear electric motor which drives a piston 85 in the cylinder portion. A centrally apertured transverse wall 86 separates the cylinder portion 82 from the motor housing portion 84 and a reciprocating drive is applied to the piston 85 from the motor by a shaft 87 sealingly extending through the aperture of the wall. The linear electric motor comprises an annular stator winding portion 90 mounted within the housing portion 84 and a co-operating driven portion 91 surrounded by the stator winding and having the shaft 87 extending from it.

A pump space or chamber 94 is defined between the piston 85 and the wall 86, and this communicates with an inlet space 95 on the other side of the piston, by way of passages 96 through the piston each controlled by a non-return valve 97. Also on this side, the piston 85 carries a concentric discharge tube 99, the interior of which communicates with the pressure chamber 94 by passages 100 controlled by a return valve 101. A pump discharge duct or pipe 102 is concentrically received, with adequate spacing, within the inlet pipe 81 and is closed by an annular end wall 104 through which the piston discharge tube 99 sealingly extends.

On energization of the motor to cause movement of the piston 85 and discharge tube 99 to the right, as shown in Figure 3, fluid in the pressure chamber 94 is expelled by way of the passages 100, the non-return valve 101 and the discharge tube 99 into a discharge space 105 constituted by the discharge pipe 102. On the return stroke of the piston, fluid in the inlet space 95 enters the pump chamber 94 by way of the passages 96 and the check valves 97, and the discharge tube 99 carries fluid into the discharge space 105 by its leftward movement, as shown. Again, the dimensions of the pump unit components are preferably chosen so that equal volumes of the fluid enter the discharge space 105 on each stroke of the piston 85.

The invention can of course be embodied in a variety of ways other than that specifically described.

Claims

1. A pump unit comprising a pump casing (5,6;61,62;82) having a variable volume pump space therein, non-return valves (16;66,67;97,101) permitting movement of a fluid to be pumped from an inlet space through the pump space to a discharge space, and drive means (20,21;54;90,91) for driving piston means (10,11;60;85) in the casing through reciprocating movements to increase and decrease the pump space alternately, the piston means being arranged to move said fluid into the discharge space on each movement of the piston means.

2. A pump unit as claimed in claim 1 wherein the piston means move substantially equal volumes of the fluid into the discharge space on each of movement of the piston means.

3. A pump unit as claimed in claim 1 or 2 wherein the piston means comprises upstream and downstream pistons (10,11) defining the pump space between them, the drive means being arranged to drive the pistons alternately towards and away from each other.

4. A pump unit as claimed in claim 3 wherein the non-return valve means comprise at least one non-return valve (16) controlling fluid flow through each of the pistons (10,11).

5. A pump unit as claimed in claim 3 or 4 wherein the drive means comprises upstream and downstream linear electric motors (20,21) acting on the upstream and downstream pistons respectively.

6. A pump unit as claimed in claim 1 or 2 wherein the casing means comprises a cylinder (61,62;82), the piston means comprises a piston (60;85) slidably guided in the cylinder and a discharge tube (56;99) extending from the piston outwardly of the cylinder into the discharge space (75;105), and the non-return valve means comprise at least one first non-return valve (66;97) controlling fluid communication between the inlet space and the pump space and at least one second non-return valve (67;101) controlling fluid communication between the pump space and the discharge tube.

7. A pump unit as claimed in claim 6 wherein the drive means is located between the cylinder and the discharge space.

8. A pump unit as claimed in claim 6 or 7 wherein the interior (70) of the cylinder other than the pump space freely communicates with the inlet space.

9. A pump unit as claimed in claim 7 or 8 wherein the first non-return valve (64) is located in the wall of the cylinder and the second non-return valve (67) is located at the junction of the piston and the discharge tube.

10. A pump unit as claimed in claim 6 wherein the cylinder (82) comprises an end portion of an inlet duct (81), the piston divides the interior of the cylinder into the inlet space (95) and the pump space (94), and the discharge space is defined by an outlet duct (102) received within the inlet duct.

11. A pump unit as claimed in claim 10 wherein the cylinder has an apertured end wall (86) defining the end of the inlet duct, and the piston has a drive shaft (87) extending therefrom remotely from the discharge tube and through the apertured end wall to receive a drive from the drive means.

12. A pump unit as claimed in claim 10 or 11 wherein the inlet duct has an extension portion (84) beyond the cylinder and the drive means is accommodated in the extension portion.

13. A pump unit as claimed in claim 10, 11 or 12 wherein the at least one first non-return valve (97) is located in the piston and the second at least one non-return valve (101) is located at the junction of the piston and the discharge tube.

14. A pump unit as claimed in any one of claims 1-4 and 6-13 wherein the drive means comprises linear electric motor means.

FIG.1.

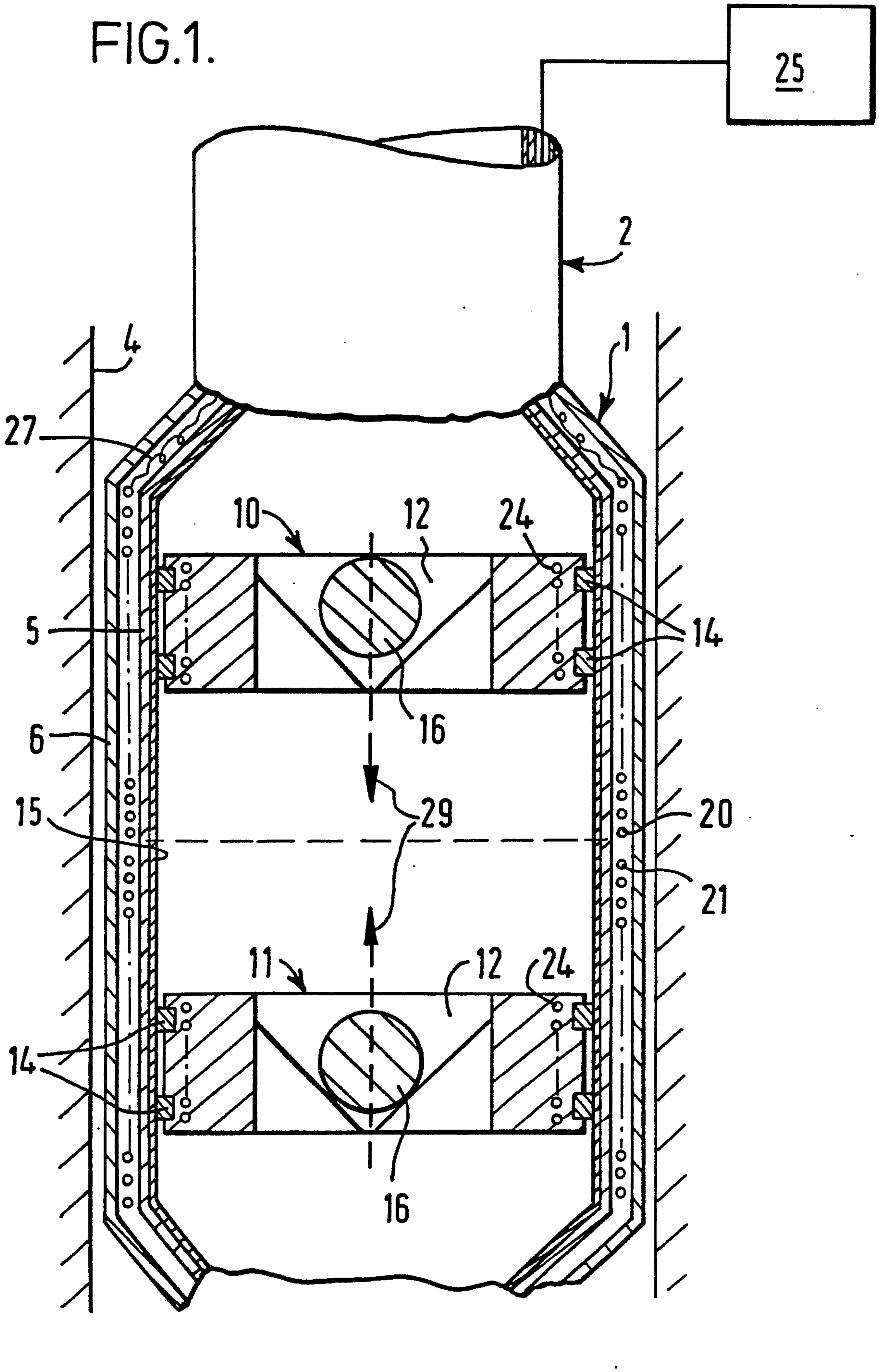
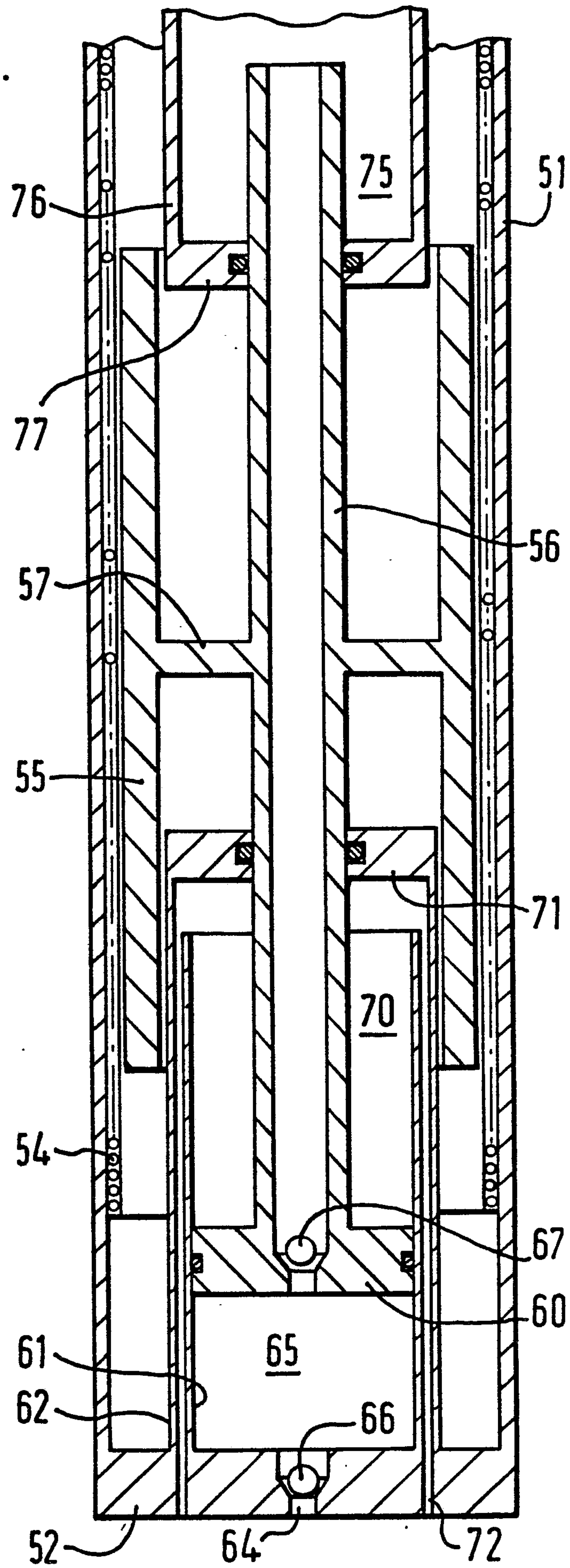


FIG. 2.



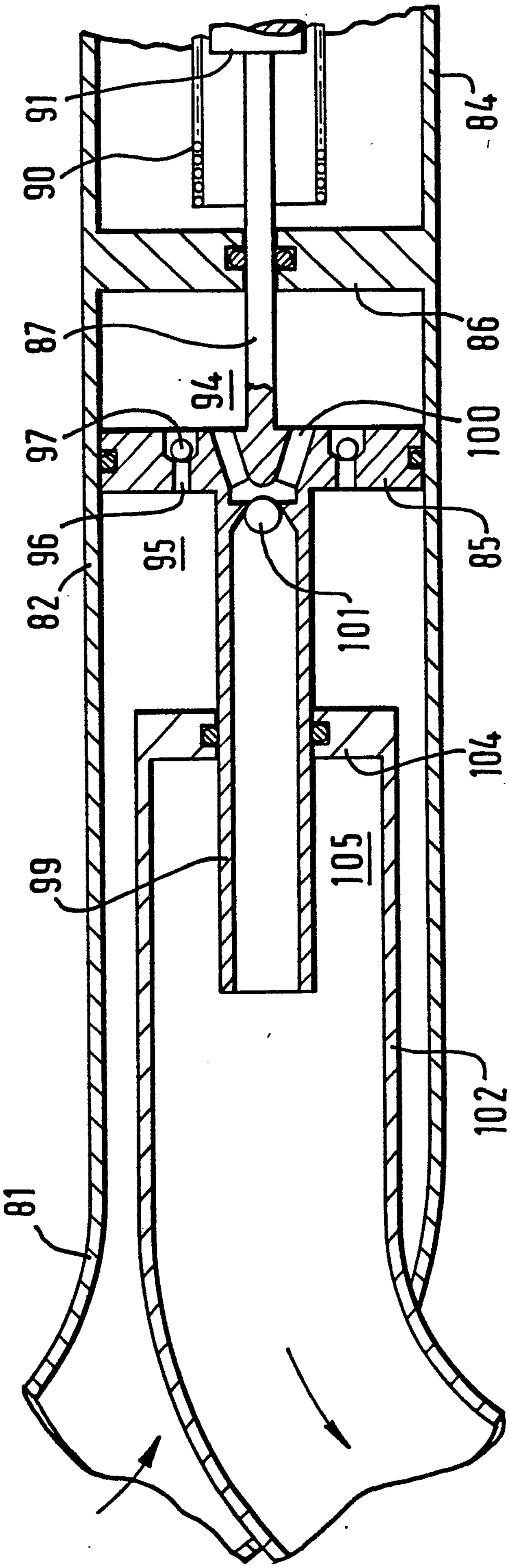


FIG. 3.