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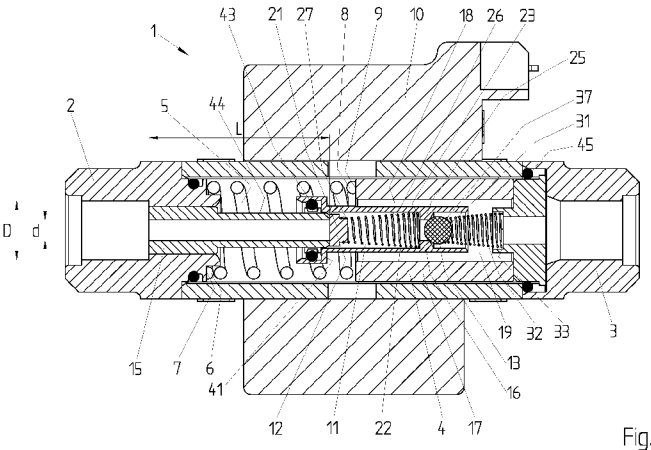


Fig. 1a

(57) Abstract: According to the present invention there is provided an electromagnetic pump (1,50) comprising, an inlet (2); an outlet (3); an intermediate chamber (11) located between said inlet (2) and said outlet (3); a first valve (12) for controlling the flow of fluid into the intermediate chamber (11), and a second valve (13) for controlling the flow of fluid out of the intermediate chamber (11); a piston (4), at least a part of which comprises ferromagnetic material, located between the inlet (2) and outlet (3), and including a channel (19) through which fluid can flow, wherein the piston (4) is moveable between a first and second position to control the opening and closing of the first and second valves (11,12); a main spring (5) which is arranged to exert a force against said piston (4) to bias the piston (4) towards its first position; a coil (10) for generating an electromagnetic field for moving said piston (4) towards its second position, against the biasing force exerted by said main spring (5); a pressure increasing tube (15) with an inner diameter (d) which is smaller than an inner diameter (D) of the inlet (2), so fluid flowing from the inlet (2) into the pressure increasing tube (15) is pressurized; said at least a portion of the length (L) of the pressure increasing tube (15) is located within said main spring (5), characterized in that the piston comprises an inner part (16) and an outer part (17) wherein the inner part (16) of the piston is secured within the outer part (17) of the piston (4), and wherein the pressure increasing tube (15) is configured to extend from the inlet (2) to within the inner part of the piston (4). There is further provided a corresponding method of manufacturing an electromagnetic pump (1,50).

WO 2014/177442 A1

Electromechanical Pump

Field of the invention

[0001] The present invention relates to an electromechanical pump, and in particularly, but not exclusively, to an electromechanical pump which comprises a pressure increasing tube which is arranged within a main spring used to move a piston in the pump. There is further provided a corresponding method of manufacturing an electromagnetic pump.

Description of related art

[0002] Figure 7a shows a longitudinal-section view of a known electromagnetic pump 70 currently used in the art. The electromagnetic pump 70 comprises a piston 71 which is made from ferromagnetic material. A pressure increasing tube 75 is further provided; the pressure increasing tube 75 is integral to the piston 71 so that the piston 71 and pressure increasing tube 75 are defined by a single component. The piston 71 defines a channel 81 through which fluid can flow from an inlet 82 to the pressure increasing tube 75 and into an intermediate chamber 77. Fluid can flow from the intermediate chamber to an outlet 79.

[0003] The piston 71 is biased towards a first position by means of a main spring 78. The electromagnetic pump 70 further comprises a coil 73; when current is passed through the coil 73, a magnetic field is generated which forces the piston 71 towards a second position.

[0004] The electromagnetic pump 70 further comprises a first valve 76 which controls the flow of fluid from the pressure increasing tube 75 into an intermediate chamber 77. A second valve 74 is provided, which controls the flow of fluid from the intermediate chamber 77 to an outlet 79. Moving the piston towards its second position creates a vacuum in the intermediate chamber 77 which causes the first valve 76 to open, , thus allowing fluid to flow from the inlet 82, through the channel 81 in the piston 71, into the pressure increasing tube 75, and into the intermediate

chamber 77. Moving the piston 71 to its first position closes the first valve 76, increases the pressure within the intermediate chamber 77; the increase in pressure within the intermediate chamber 77 causes the first valve 76 is forced to close and the second valve 74 to open causes. Specifically the increase in pressure with an intermediate chamber 77 causes the fluid within the intermediate chamber 77 to force the second valve to open, thus enabling fluid to flow from the intermediate chamber 77 to the outlet 79.

[0005] Figure 7b shows the electromagnetic pump 70 when piston 71 in its second position and Figure 7c shows the electromagnetic pump 70 when the piston in its first position.

[0006] Disadvantageously, each of the main spring 78, pressure increasing tube 75 and piston 71, are distributed along the length of the electromagnetic pump 70, each at a different, exclusive, position along the length of the electromagnetic pump 70. Accordingly the electromagnetic pump 70 is long and not compact enough for certain applications.

[0007] Additionally, it is important that the main spring 78, pressure increasing tube 75 and piston 71 are coaxial, to allow the piston 71 to smoothly move between its first and second position. As the main spring 78, pressure increasing tube 75 and piston 71 are each distributed along the length of the electromagnetic pump 70, at different, exclusive, positions, these components are more susceptible to becoming displaced from being coaxial with one another if a force is applied to an end of the electromagnetic pump 1. For example, a force may be applied to and end of the electromagnetic pump 1 when screwing the end of the electromagnetic pump 1 to a structure to secure the electromagnetic pump 1 to the structure; this force may cause displacement of the pressure increasing tube 75 so that it is no longer coaxial with the main spring 78 and piston 71.

[0008] Furthermore, since the pressure increasing tube 75 is integral to the piston 71 so that the piston 71 and pressure increasing tube 75 are

defined by a single component, it is difficult to make the piston 71 and pressure increasing tube 75 from different materials.

[0009] Other electromagnetic pump solutions are disclosed in documents FR1555291 and DE2410768. Although the pumps disclosed in both these documents include a form of pressure increasing tube, the configurations of the pressure increasing tubes are not optimum. Disadvantageously, due to the configuration of the pressure increasing tubes in the pumps of FR1555291 and DE2410768 fluid flowing through the pumps will suffer a decrease in pressure before reaching the piston.

[0010] It is an aim of the present invention is obviate, or mitigate at least some of the above-motioned disadvantages.

Brief summary of the invention

[0011] According to the invention, there is provided an electromagnetic pump comprising, an inlet; an outlet; an intermediate chamber located between said inlet and said outlet; a first valve for controlling the flow of fluid into the intermediate chamber, and a second valve for controlling the flow of fluid out of the intermediate chamber; a piston, at least a part of which comprises ferromagnetic material, located between the inlet and outlet, and including a channel through which fluid can flow, wherein the piston is moveable between a first and second position to control the opening and closing of the first and second valves; a main spring which is arranged to exert a force against said piston to bias the piston towards its first position; a coil for generating an electromagnetic field for moving said piston towards its second position, against the biasing force exerted by said main spring;a pressure increasing tube with an inner diameter which is smaller than an inner diameter of the inlet, so fluid flowing from the inlet into the pressure increasing tube is pressurized; wherein said at least a portion of the length of the pressure increasing tube is located within said main spring.

[0012] Advantageously, locating at least a portion of the length of the pressure increasing tube within said main spring ensures that at least part of the pressure increasing tube and at least a part of the main spring share same position along the length of the electromagnetic pump, thus reducing the length electromagnetic pump. Furthermore, the pressure increasing tube will now be located in a more central position along the length of the electromagnetic pump thus ensuring that the pressure increasing tube is less susceptible to becoming displaced, from being coaxial with the piston, by a force applied to an end of the electromagnetic pump.

[0013] Preferably when the piston is in its first position the first valve is opened and the second valve is closed, and when the piston is in its second position the first valve is closed and the second valve is opened. Thus when the piston is in its first position the intermediate chamber can fill with fluid, and when the piston is in its second position the fluid within the intermediate chamber can pass from the intermediate chamber to the outlet.

[0014] Preferably pressure within said intermediate chamber is reduced when the first valve is open and the piston is moved towards its first position, so that fluid can flow from the inlet into the intermediate chamber. Preferably pressure within said intermediate chamber is increased when the first valve is closed and the piston is moved towards its second position, to compresses a fluid within said intermediate chamber, so that said compressed fluid can flow from the intermediate chamber towards the outlet.

[0015] The main spring is preferably a helical spring.

[0016] The intermediate chamber may be separated from said inlet by a first valve and from said outlet by a second valve.

[0017] Fluid preferably flows from the inlet towards the outlet.

[0018] The pressure increasing tube may be located upstream of said piston.

[0019] Preferably the pressure increasing tube is located between the inlet and the intermediate chamber. Preferably, the pressure increasing tube is arranged to fluidly connect the inlet with the intermediate chamber.

[0020] The pressure increasing tube may be integral to said inlet. Advantageously this will reduce the number of parts in the electromagnetic pump. Furthermore, this will enable easier manufacture of the electromagnetic pump; for example the manufacture of the electromagnetic pump would be made easier since the inlet and pressure increase tube could be made using a single moulding step (e.g. a single injection moulding step).

[0021] The pressure increasing tube and piston may be mechanically independent. Advantageously this will make is easier to make the pressure increasing tube and piston from different materials. For example, the piston could be made from ferromagnetic material, and the pressure increasing tube could be made from non-ferromagnetic material, such as plastic or polymer, or any other suitable non-ferromagnetic metal. This will also aid in reducing the cost of the electromagnetic pump.

[0022] Preferably the inner diameter of the pressure increasing tube is of a length necessary to pressurize fluid which passes through the pressure increasing tube to a predefined pressure.

[0023] The piston may comprise an inner part and an outer part.

[0024] Preferably the piston and the pressure increasing tube are coaxial. Most preferably the inner part of the piston, the outer part of the piston and the pressure increasing tube are coaxial.

[0025] Preferably the inner part and outer part are mechanically independent. Advantageously this will make is easier to make the inner and outer parts of the piston from different materials. For example, the outer part of the piston could be made from ferromagnetic material, and the inner part of the piston could be made from plastic, or any other non-ferromagnetic metal. This will also aid in reducing the cost of the electromagnetic pump.

[0026] The inner part of the piston may be secured within the outer part of the piston. Preferably the inner part of the piston is held by friction within the outer part of the piston. Preferably an outer diameter of the inner part of the piston is substantially equal to an inner diameter of the outer part, so that the inner part of the piston can be held by friction within the outer part of the piston.

[0027] Preferably the pressure increasing tube has an inner diameter which is smaller than an inner diameter of the piston. Preferably the pressure increasing tube has an inner diameter which is smaller than the outer diameter of the piston. Most preferably the pressure increasing tube has an inner diameter which is smaller than an inner diameter of the inner part of the piston. Preferably the pressure increasing tube has an inner diameter which is smaller than an outer diameter of the inner part of the piston. Most preferably the pressure increasing tube has an inner diameter which is smaller than an inner diameter of the outer part of the piston. Preferably the pressure increasing tube has an inner diameter which is smaller than an outer diameter of the outer part of the piston.

[0028] The inner part of the piston may abut the outer part of the piston. The main spring may be arranged to urge the inner part against the outer part. The main spring will thus ensure that the inner part of the piston is held in abutment with the outer part of the piston.

[0029] Preferably the inner part comprises an annular projection and the main spring is arranged to apply a biasing force to the annular projection to urge the inner part of the piston against the outer part of the piston.

Preferably the main spring is arranged to apply a biasing force to the annular projection so that the annular projection urged to abut an end of the outer part of the piston.

[0030] The piston may define the intermediate chamber. Accordingly, as the piston is moved between its first and second positions, the intermediate chamber will also be moved between a first and second position.

[0031] The intermediate chamber is preferably defined by the inner part of the piston.

[0032] The inner part of the piston preferably comprises a tubular member.

[0033] The outer part of the piston preferably comprises a tubular member.

[0034] Preferably the inner diameter of the pressure increasing tube is smaller than an inner diameter of the intermediate chamber. The inner diameter of the pressure increasing tube may be smaller than an inner diameter of the channel defined in the outer part of the piston. The inner diameter of the pressure increasing tube may be smaller than an inner diameter of the outlet.

[0035] At least a portion of the length of said pressure increasing tube may extend into intermediate chamber. At least a portion of the length of said pressure increasing tube may extend into the inner part of the piston. Preferably the pressure increasing tube is telescopically arranged within the inner part of the piston.

[0036] The inner part of the piston may further comprise an annular extension provided on an inner surface of the inner part of the piston.

[0037] The first valve may comprise a first plug and a first spring. A first end of the first spring may be attached to the piston. Preferably the first

end of the spring is attached to inner part of the piston. Most preferably the first end of the spring is attached to said annular extension provided on the inner part of the piston. The first plug may be fixed to a second, opposite, end of the first spring. Preferably the first end of the first spring is the end of the first spring which is closest the outlet, and the second end of the first spring is the end of the first spring which is closest the inlet.

[0038] The first spring is preferably arranged to bias the first plug towards plugging the pressure increasing tube.

[0039] Preferably when the piston is moved towards its first position, the piston is moved towards the outlet. Therefore moving the piston towards its first position reduces the biasing force applied by the first spring to the first plug. The biasing force applied by the first spring to the first plug is decreased as the first spring is less compressed when the piston is moved towards its first position. Preferably when the piston is moved to its first position the biasing force applied by the first spring to the first plug is less than the force applied to the first plug by fluid inside the pressure increasing tube. Also when the piston is moved towards its first position a vacuum is created in the intermediate chamber. Thus, when the piston is in its first position the first plug will be unplugged from the pressure increasing tube and due to the vacuum which is in the intermediate chamber, fluid is sucked out of the pressure increasing tube into the intermediate chamber.

[0040] Preferably when the piston is moved towards it second position the piston is moved towards the inlet. Therefore moving the piston towards its first position increases the biasing force applied by the first spring to the first plug. The biasing force applied by the first spring to the first plug is increased as the first spring is compressed more when the piston is moved towards its second position. Preferably when the piston is moved to its second position the biasing force applied by the first spring to the first plug is greater than the force applied to the first plug by fluid inside the pressure increasing tube. Thus, when the piston is in its second position the

first plug will plug the pressure increasing tube to prevent the flow of fluid from the pressure increasing tube into the intermediate chamber.

[0041] The second valve may comprise a second plug and a second spring. A first end of the second spring may be attached to the outlet. Alternatively the first end of the second spring may be attached to the outer part of the piston. For example the outer part of the piston may further comprise a collar, and the first end of the second spring may be attached to the collar provided on the outer part of the piston.

[0042] The second plug may be fixed to a second, opposite, end of the second spring.

[0043] The second spring is preferably arranged to bias the second plug towards plugging the inner part of the piston. The second spring is preferably arranged to bias the second plug towards plugging the inner part of the piston so as to prevent the fluid from flowing out of the intermediate chamber towards the outlet.

[0044] Preferably the first end of the second spring is the end of the second spring which is closest the outlet, and the second end of the second spring is the end of the second spring which is closest the inlet.

[0045] Preferably, when the piston is moved towards its first position, the piston is moved towards the outlet. Therefore moving the piston towards its first position increases the biasing force applied by the second spring to the second plug. The biasing force applied by the second spring to the second plug is increased as the second spring is compressed more when the piston is moved towards it first position. Preferably when the piston is moved to its first position the biasing force applied by the second spring to the second plug is greater than the force applied to the second plug by fluid inside the intermediate chamber. Thus when the piston is in its first position the second plug will plug the inner part of the piston to prevent the flow of fluid from the intermediate chamber into the channel defined in the outer part of the piston and from the channel defined in the outer

part of the piston into the intermediate chamber. Ultimately, the second plug will thus prevent the flow of fluid from the intermediate chamber to the outlet and/or from the outlet to the intermediate chamber.

[0046] Preferably when the piston is moved towards it second position the piston is moved towards the inlet. Therefore moving the piston towards its first position decreases the biasing force applied by the second spring to the second plug. The biasing force applied by the second spring to the second plug is decreased as the second spring is less compressed when the piston is moved towards it second position. Preferably when the piston is moved to its second position the biasing force applied by the second spring to the second plug is less than the force applied to the second plug by fluid inside the intermediate chamber. Also when the piston is moved towards its second position the pressure inside the intermediate chamber is increased, thus any fluid within the intermediate chamber will become pressurized. Thus when the piston is in its second position the second plug will be unplugged from the inner part of the piston by pressurized fluid in the intermediate chamber, so that the pressurized fluid within the intermediate chamber can flow from the intermediate chamber into the channel defined in the outer part of the piston. Ultimately, the second plug will thus be unplugged from the inner part of the piston to allow fluid to flow from the intermediate chamber into the outlet.

[0047] Accordingly the first and second springs may be contracted because of the pressure changes which occur within the intermediate chamber of the electromagnetic pump. The first valve is opened when the volume of the intermediate chamber is decreased (i.e. when the vacuum is created in the intermediate chamber), the vacuum will also aid in maintaining the second value closed; this occurs when the piston is moved to its first position. The second valve is opened when the volume in the intermediate chamber increased (i.e. when the pressure inside the intermediate chamber is increased to pressurize the liquid in the intermediate chamber), the increase in pressure inside the intermediate chamber will also aid in maintaining the first valve closed; this occurs when the piston is moved to its second position.

[0048] Preferably when the piston is in its first position it is closer to the outlet than the inlet. Preferably when the piston is in its second position it is closer to the inlet than the outlet.

[0049] Preferably when the piston is in its first position the telescopically arrangement of the inner part of the piston and the pressure increasing tube is at a maximum extension. Preferably when the piston is in its second position, the telescopically arrangement of the inner part of the piston and the pressure increasing tube is collapsed.

[0050] Preferably, when the piston is in its first position, the first plug is removed from the pressuring increasing tube, to unplug the pressure increasing tube, to allow fluid to flow from the pressure increasing tube into the intermediate chamber. Preferably when the piston is in its second position, the first plug plugs the pressure increasing tube, to prevent fluid from flowing from the intermediate chamber into the pressure increasing tube and/or from the intermediate chamber into the pressure increasing tube.

[0051] Preferably, when the piston is in its first position, the second plug plugs the inner part of the piston, to prevent fluid from flowing out of the channel defined in the outer part of the piston into the intermediate chamber and/or from the intermediate chamber into the channel defined in the outer part of the piston, and into the outlet. Preferably, when the piston is in its second position, the second plug is removed from the inner part of the piston, to unplug the inner part of the piston, to allow fluid to flow from the intermediate chamber into the channel defined in the outer part of the piston, and into the outlet.

[0052] The first and/or second plugs may have a spherical shape. The first and/or second plugs may have a stepped-cylindrical shape. It will be understood that the first and/or second plugs may have any suitable shape or configuration.

[0053] At least one clearance channel may be provided between the inner part of the piston and the outer part of the piston. Preferably, a plurality of clearance channels is provided between the inner part of the piston and the outer part of the piston.

[0054] One of the outer part or inner part of the piston may be comprise a ferromagnetic material and the other part may comprise non-ferromagnetic material. One of the outer part or inner part of the piston may be composed of a ferromagnetic material and the other part may be composed of a non-ferromagnetic material. For example, the outer part of the piston may be composed of a ferromagnetic material and the inner part of the piston may be composed of a non-ferromagnetic material. For example the inner part of the piston may be made from plastic or polymer.

[0055] A method of manufacturing an electromagnetic pump according to any one of the above-mentioned electromagnetic pumps, comprising the steps of, providing an inlet; providing an outlet; providing an intermediate chamber between said inlet and said outlet; providing a first valve for controlling the flow of fluid into the intermediate chamber, and providing a second valve for controlling the flow of fluid out of the intermediate chamber; providing a piston between the inlet and outlet, wherein the piston comprises a channel through which fluid can flow and at least a part of the piston comprises ferromagnetic material, and wherein the piston is moveable between a first and second position to control the opening and closing of the first and second valves; providing a main spring, and arranging the main spring to exert a force against said piston to bias the piston towards its first position; providing a coil for generating an electromagnetic field for moving said piston towards its second position, against the biasing force exerted by said main spring; providing a pressure increasing tube with an inner diameter which is smaller than an inner diameter of the inlet, so fluid flowing from the inlet into the pressure increasing tube is pressurized; wherein the method further comprises the step of arranging the pressure increasing tube such that at least a portion of the length of the pressure increasing tube is located within said main spring.

[0056] Preferably the step of providing a piston comprises providing a piston which comprises an inner part and an outer part, wherein one of the inner or outer parts is composed of a ferromagnetic material and the other part is composed of non-ferromagnetic material.

[0057] Preferably the inner part and outer part are mechanically independent.

[0058] The step of providing a piston may comprise providing a piston which comprises an inner part and an outer part, and the method comprising the step of arranging the inner part within the outer part, so that the inner part is held by friction within the outer part of the piston.

[0059] The step of providing a piston may comprise providing a piston which comprises an inner part and an outer part, and the method comprises the step of arranging the main spring is to urge the inner part against the outer part, so that the main spring will hold the inner part in abutment with the outer part of the piston.

Brief Description of the Drawings

[0060] Embodiment of the present invention will be described, by way of example only, with reference to the following figures, in which:

Fig. 1a shows a longitudinal-section view of an electromagnetic pump according to an embodiment of the present invention;

Fig. 1b provides a perspective view of a piston used in the electromagnetic pump shown in Fig. 1a;

Fig. 1b provides a cross-section view of a piston used in the electromagnetic pump shown in Fig. 1a;

Fig. 2 provides a longitudinal-section view of an electromagnetic pump of Fig. 1a, during use, when the piston is in its first position;

Fig. 3 provides a longitudinal-section view of an electromagnetic pump of Fig. 1a, during use, when the piston is in its second position;

Fig. 4a provides a longitudinal-section view of an electromagnetic pump according to a further embodiment of the present invention;

Fig. 4b provides a perspective view of a piston used in the electromagnetic pump shown in Fig. 4a;

Fig. 5 provides a longitudinal-section view of an electromagnetic pump of Fig. 4a, during use, when the piston is in its first position;

Fig. 6 provides a longitudinal-section view of an electromagnetic pump of Fig. 4a, during use, when the piston is in its second position;

Fig. 7a shows a longitudinal-section view of a known electromagnetic pump;

Fig. 7b shows the electromagnetic pump of Fig. 7a when the piston is in its second position;

Fig. 7c shows the electromagnetic pump of Fig. 7a when the piston is in its first position.

Detailed description of possible embodiments of the invention

[0061] Figure 1a shows a cross-sectional view of an electromagnetic pump 1 according to an embodiment of the present invention. The electromagnetic pump 1 comprises an inlet 2, an outlet 3 and a piston 4located between the inlet 2 and outlet 3.

[0062] The electromagnetic pump 1 further comprises a main spring 5. One end 6 of the main spring 5 abuts a surface 7 of the inlet 2 and the opposite end 8 of the main spring 5 abuts a surface 9 of the piston 4, so as to exert a force against said piston 4 to bias the piston toward a first position. A coil 10 is further provided for generating an electromagnetic field which can move said piston 4, against the biasing force exerted by said main spring 5, towards a second position. In this embodiment the main spring 5 is a helical spring.

[0063] The piston 4 comprises an inner part 16 and an outer part 17. At least part of the inner part 16 is arranged within the outer part 17, and both the inner and outer parts 16,17 of the piston 4 are fixed relatively to each other. In this particular example the majority of the inner part 16 is arranged within the outer part 17. The inner part 16 of the piston 4 is held by friction within the outer part 17, so that the inner and outer parts 16,17 are fixed relative to each other. In order for the inner part 16 of the piston 4 to be held by friction within the outer part 17 of the piston 4 the maximum (effective) outer diameter "D_o'" of the inner part 16 of the piston 4 is preferably substantially equal to the inner diameter "d_i" of the outer part 17 of the piston 4, as is illustrated in Figures 1b and c. It can also be seen in Figures 1a, b and c that the inner part 4 of the piston comprises a tubular member and that the outer part of the piston also comprises a tubular member.

[0064] At least one clearance-channel 18 is provided between the inner part 16 and the outer part 17 of the piston 4. Figure 1b and c show three clearance-channels 18.

[0065] At least a part of the piston 4 comprises ferromagnetic material. In this example, the outer part 17 comprises ferromagnetic material and the inner part 16 of the piston 4 comprises plastic (or any other suitable non- ferromagnetic material). . However, it will be understood that it that of either the inner part 16 of outer part 17 may comprise ferromagnetic material while the other part 16,17 comprises another material; or both the inner part 16 and outer part 17 could both comprise ferromagnetic material.

[0066] The inner part 16 of the piston 4 defines an intermediate chamber 11. Since the piston 4 is moveable between a first and second position, the intermediate chamber 11 which is defined by the inner part 16 of the piston 4 is, in effect, moveable between the first and second position. The piston 4 and therefore the intermediate chamber 11, is located between said inlet 2 and said outlet 3.

[0067] The outer part 17 of the piston 4 defines a channel 19 through which fluid can flow. Specifically, the outer part 17 of the piston 4 defines a channel 19 through which fluid, which flows out of the intermediate chamber 11, can flow to the outlet 3.

[0068] A pressure increasing tube 15 is provided which fluidly connects the inlet 2 with the intermediate chamber 11. A portion of the length "L" of the pressure increasing tube 15 is located within the main spring 5; in this example the majority of the length "L" of the pressure increasing tube 15 is located within the main spring 15. The pressure increasing tube 15 is also mechanically independent of the piston 4. The pressure increasing tube 15 has an inner diameter 'd' which is smaller than an inner diameter 'D' of the inlet 2, so that the pressure in the fluid flowing from the inlet 2 into the pressure increasing tube 15 is increased. During use the fluid preferably flows from the inlet 2 towards the outlet 3, therefore the pressure increasing tube 15 can be considered to be located upstream of said piston 4.

[0069] A first valve 12 is provided to control the flow of fluid from the pressure increasing tube 15 into the intermediate chamber 11. A second valve 13 is provided to control the flow of fluid from the intermediate chamber 11 to the channel 19 defined by the outer part 17 of the piston. Ultimately the first and second valves 12,13 control the flow of fluid from the inlet 2 into the intermediate chamber 11 and from the intermediate chamber 11 to the outlet 3, respectively. The first valve 12 comprises a first plug 21 and a first spring 22. A first end 23 of the first spring 22 is attached to an annular extension 25 provided on the inner surface 26 of the inner part 16 of the piston 4; and the first plug 21 is fixed to a second, opposite, end 27 of the first spring 22. The first spring 22 extends from the annular extension 25 to proximate the pressure increasing tube 15, and biases the first plug 21 plugs towards plugging the pressure increasing tube 15. The second valve 13 comprises a second plug 31 and a second spring 32. A first end 33 of the second spring abuts the outlet 3 and the second plug 31 is fixed to a second, opposite, end 37 of the second spring 32. The second spring extends from the outlet 3 to proximate the inner part 16 and biases the second plug 31 towards plugging the inner part 16 of the piston (thus plugging the intermediate chamber 11). In this particular example the second plug 32 comprises a spherical member 32 and the first plug 21 comprises a stepped-cylindrical member 21; however it will be understood that the first and second plugs 21, 31 may have any suitable shape or configuration.

[0070] At one end 41 of the inner part 16 of the piston 4, a portion of the length of said pressure increasing tube 15 extends into the inner part 16 of the piston 16. Specifically, the pressure increasing tube 15 is telescopically arranged within the inner part 16 of the piston. A first seal 43 is located between an outer surface 44 of the pressure increasing tube 15 and the inner surface 26 of the inner part 16 of the piston 4. In this particular example the first seal 43 is defined by an o-ring; however it will be understood that any suitable seal may be provided. The first seal 43 will prevent fluid from flowing out of the intermediate chamber 11 between the pressure increasing tube 15 and inner part 16 of the piston 4.

[0071] An o-ring45 is provided between the outer part 17 of the piston 4 and the outlet 3. The o-ring 45 acts as a shock absorber. Advantageously, the pressure increasing tube 15 is arranged so that at least a portion of its length "L" is located within said main spring 5. Locating at least a portion of the pressure increasing tube 15 within the main spring 5 reduces the total length of the electromagnetic pump 1. Additionally, the pressure increasing tube 15 is located in a more central position in the electromagnetic pump 1, thus reducing the chances of the pressure increasing tube 15 becoming displaced from being coaxial with the piston 4 if a force (such as a radial force) is applied to an end of the electromagnetic pump 1. In will be understood that the pressure increasing tube 15 may be configured to be integral to said inlet 2, thus reducing the number of parts in the electromagnetic pump 1. Furthermore, in this example since the pressure increasing tube 15 and piston 4 are mechanically independent, it is easier to make both components from different material; for example, if the piston 4 is made from ferromagnetic material, the pressure increasing tube 15 can be easily made from another material, such as non-ferromagnetic material like plastic, as it is mechanically independent to the piston 4.

[0072] Figures 2 and 3 illustrate the electromechanical pump 1 during use. Referring first to figure 2, fluid flows from the inlet 2 into the pressure increasing tube 15. As the diameter "d" of the pressure increasing tube 15 is smaller than the diameter "D" of the inlet 2 pressure in fluid which flows from the inlet 2 into the pressure increasing tube 15 is increased. The biasing force exerted on the piston 4 by the main spring 5 moves the piston 4 to its first position. Therefore Figure 2 shows the piston in its first position. Since the first spring 22 of the first valve 12 is attached at its first end 23 to the annular extension 25 provided on inner part 16 of the piston 4, moving the piston 4 towards its first position moves the first end of the spring 22 away from the pressure increasing tube 15 and thus reduces the biasing applied by the first spring 22 to the first plug 21. At the point when biasing force applied by the first spring to the first plug 21, is less than the force applied to the first plug 21 by the fluid in the pressure increasing tube 15. Also when the piston 4 is moved towards its first position the

volume of the intermediate chamber 11 is increased and thus a vacuum is created in the intermediate chamber 11. The vacuum and the fluid will thus force the first plug 21 to become unplugged from the pressure increasing tube 15, and fluid will be sucked out of the pressure increasing tube 15 into the intermediate chamber 11. Simultaneously, as the piston 4 is moved towards its first position, the piston 4 is moved towards the inlet. Consequently the second spring 32 of the second valve 13 will become more compressed between the piston and outlet 3, causing an increase in the biasing force applied by the second spring 32 to the second plug 32. The increase of the biasing force of the second spring 32 will ensure that inner part 16 of the piston remains plugged by the second plug 31 even when fluid has passed from the pressure increasing tube 15 into the intermediate chamber 11. Also the vacuum which is created in the intermediate chamber 11 will suck the second plug 32 towards plugging the inner part 16. Thus when the piston 4 is moved to its first position the second valve 13 will prevent the fluid from passing out of the outlet 3 to the intermediate chamber 11 and also out of the intermediate chamber 11 into the outlet 3.

[0073] It is important to note that even when the piston 4 is in its first position, a portion of the length of the pressure increasing tube 15 extends into the intermediate chamber 11.

[0074] Once the intermediate chamber 11 has been filled with fluid, current is then passed through the coil 10. A magnetic field is generated which moves the piston 4 against the biasing force of the main spring 5, towards its second position.

[0075] Figure 3 shows the piston 4 in its second position. When the piston 4 is moved towards its second position the piston 4, the volume of the intermediate chamber 11 is decreased; accordingly the fluid within the intermediate chamber 11 is increased and becomes pressurized. The pressurized fluid pushes the first plug 21, of the first valve 12 towards the pressure increasing tube 15 so that first plug 21 plugs the pressure increasing tube 15. Also when piston 4 is moved towards its second

position the piston 4 the first plug 21 is moved to plug the pressure increasing tube 15 and the first spring 22 is compressed between the annular extension 25 on the inner part 16 of the piston and the first plug 21 so as to increase the biasing force applied by the first spring 22 to the first plug 21. At the point where the force applied by the first spring 22 to the first plug 21 plus the force applied to the plug by the pressurized fluid within the intermediate chamber 11, combined, is greater than the force applied to the first plug 21 by the pressurized fluid in the pressure increasing tube 15, the first plug 21 will plug the pressure increasing tube 15 to prevent the flow of the pressurized fluid from the intermediate chamber 11 to the pressure increasing tube 15 and from the pressure increasing tube 15 into the intermediate chamber 11 . Simultaneously, as the piston 4 is moved towards its second position, the biasing force applied by the second spring 32 to the second plug 31 in the second valve 13, is reduced. Also the pressurized fluid within the intermediate chamber 11 will push the second plug 31 away from the inner part 16 of the piston 4 thus urging the second plug 31 to unplug the inner part 16 of the piston 4. At the point when biasing force applied by the second spring 32 to the second plug 31, is less than the force applied by the pressurized fluid in the intermediate chamber 11 to the second plug 31, the pressurized fluid in the intermediate chamber 11 will force the second plug 32 to become unplugged from the inner part 16 of the piston, and pressurized fluid will flow from the intermediate chamber 11 into the channel 19 defined in the outer part 17 of the piston, and subsequently into the outlet 3.

[0076] In summary, moving the piston 4 to its first position opens the first valve 12 and closes the second valve 13, while moving the piston 4 to its second position closes the first valve 12 and opens the second valve 13.

[0077] The piston can be continuously, alternatively, moved between its first and second positions, to provide a substantially, continuous flow of fluid from the inlet 2 to the outlet 3.

[0078] Figure 4a shows a cross-sectional view of an electromagnetic pump 50 according to a further embodiment of the present invention. The

electromagnetic pump 50 comprises many of the same features as the electromagnetic pump shown in Figures 1a-3 and like features are awarded the same reference numbers.

[0079] Unlike the electromagnetic pump1 shown in Figures 1a-3 the electromagnetic pump 50 comprises a different type of piston 4. Furthermore, the first end 33 of the second spring 32 of the second valve 13, abuts a collar 53 provided on an inner surface 55 of the outer part 17 of the piston.

[0080] The electromagnetic pump 50 comprises a piston 4 which has an inner part 56 and an outer part 57. Figure 4b provides a perspective view of the piston 4. The inner and outer parts 56, 57 are similar to the inner and outer parts 16,17 of the piston 4 provided in the electromagnetic pump 1, in that both the inner and outer parts 56, 57 comprises tubular members. Clearance channels 18 are also provided between the inner and outer parts 56, 57. The outer part 57 further comprises a collar 53 against which the first end 33 of the second spring 32 of the second valve 13, abuts. It can be seen from Figure 4a that the outer part 57 comprises chamfered edges 58a,b, and an end 69 of the inner part 56 abuts these chamfered edges 58a,b.

[0081] Importantly, the inner part 56 of the piston 4 is substantially located outside of the outer part 57 of the piston. The inner part 56 of the piston 4 further comprises an annular projection 59. One end 6 of the main spring 5 abuts the surface 7 of the inlet 2 and the opposite end 8 of the main spring 5 abuts the annular projection 59 on the inner part 56 of the piston 4, so as to urge the inner part 56 of the piston 4 towards abutting a face 61 of the outer part 56. Thus, unlike the electromagnetic pump 1 shown in Figure 1a-3 wherein the inner part 16 is frictionally held within the outer part 17 of the piston 4, in the electromagnetic pump 50 the inner part 56 of the piston is outside of the outer part 57 of the piston 4 and is held in abutment with the outer part 57 by means of the main spring 5 which is arranged to bias the annular projection 59 towards a face 61 of the outer part 57.

[0082] Advantageously, the electromagnetic pump 50 is easier to manufacture; since the inner part 56 of the piston 4 is not held by friction within the outer part of the piston 57, the outer diameter of the inner part 56 does not need to be substantially equal to the inner diameter of the outer part 57. Accordingly, this allows for more tolerance in component dimensions during manufacture.

[0083] Figures 5 and 6 illustrate the electromechanical pump 50 during use. Figure 5 illustrates the electromagnetic pump 50 when the piston 4 has been moved to its first position. Figure 6 illustrates the electromagnetic pump 50 when the piston 4 has been moved to its second position. The electromechanical pump 50 operates in the same manner as described above for electromechanical pump 1.

[0084] Various modifications and variations to the described embodiments of the invention will be apparent to those skilled in the art without departing from the scope of the invention as defined in the appended claims. Although the invention has been described in connection with specific preferred embodiments, it should be understood that the invention as claimed should not be unduly limited to such specific embodiment.

Claims

1. Electromagnetic pump (1,50) comprising:

an inlet (2);

an outlet (3);

an intermediate chamber (11) located between said inlet (2) and said outlet (3);

a first valve (12) for controlling the flow of fluid into the intermediate chamber (11), and a second valve (13) for controlling the flow of fluid out of the intermediate chamber (11);

a piston (4), at least a part of which comprises ferromagnetic material, located between the inlet (2) and outlet (3), and including a channel (19) through which fluid can flow, wherein the piston (4) is moveable between a first and second position to control the opening and closing of the first and second valves (11,12);

a main spring (5) which is arranged to exert a force against said piston (4) to bias the piston (4) towards its first position;

a coil (10) for generating an electromagnetic field for moving said piston (4) towards its second position, against the biasing force exerted by said main spring (5);

a pressure increasing tube (15) with an inner diameter (d) which is smaller than an inner diameter (D) of the inlet (2), so fluid flowing from the inlet (2) into the pressure increasing tube (15) is pressurized;

said at least a portion of the length (L) of the pressure increasing tube (15) is located within said main spring (5), characterized in that the piston comprises an inner part (16) and an outer part (17) wherein the inner part (16) of the piston is secured within the outer part (17) of the piston (4), and wherein the pressure increasing tube (15) is configured to extend from the inlet (2) to within the inner part of the piston (4).

2. An electromagnetic pump according to claim 1, wherein said pressure increasing tube is located upstream of said piston.

3. An electromagnetic pump according to claim 1 or 2, wherein said the pressure increasing tube is integral to said inlet.

4. An electromagnetic pump according to any one of claims 1-3, wherein said pressure increasing tube and piston are mechanically independent.

5. An electromagnetic pump according to any one of claims 1-4, wherein the inner part of the piston abuts the outer part of the piston, and wherein the main spring is arranged to urge the inner part against the outer part.

6. An electromagnetic pump according to any one of claims 1-5, wherein the piston defines the intermediate chamber.

7. An electromagnetic pump according to any one of claims 1-6, wherein the pressure increasing tube extends into intermediate chamber.

8. An electromagnetic pump according to any one of claims 1-7, wherein the first valve comprises a first plug and a first spring and a first end of the first spring is attached to the piston and a first plug is fixed to a second, opposite, end of the first spring.

9. An electromagnetic pump according to any one of claims 1-8, wherein the second valve comprises a second plug and a second spring and a first end of the second spring is attached to the outlet or an outer part of the piston, and the second plug is fixed to a second, opposite, end of the second spring.

10. An electromagnetic pump according to any one of claims 1-9, wherein at least one clearance channel is provided between the inner part of the piston and the outer part of the piston.

11. An electromagnetic pump according to any one of claims 1-10, wherein the outer part of the piston is made of a ferromagnetic material and the inner part of the piston is made of a different material.

12. A method of manufacturing an electromagnet pump (1,50) according to claim 1, the method comprising the steps of,

providing an inlet (2);

providing an outlet (3);

providing an intermediate chamber (11) between said inlet (2) and said outlet (3);

providing a first valve (12) for controlling the flow of fluid into the intermediate chamber (11), and providing a second valve (13) for controlling the flow of fluid out of the intermediate chamber (11);

providing a piston (4) between the inlet (2) and outlet (3), wherein the piston (4) comprises a channel (19) through which fluid can flow and at least a part of the piston (4) comprises ferromagnetic material, and wherein the piston (4) is moveable between a first and second position to control the opening and closing of the first and second valves (12,13);

providing a main spring (5), and arranging the main spring (5) to exert a force against said piston (4) to bias the piston (4) towards its first position;

providing a coil (10) for generating an electromagnetic field for moving said piston (4) towards its second position, against the biasing force exerted by said main spring (5);

providing a pressure increasing tube (15) with an inner diameter (d) which is smaller than an inner diameter (D) of the inlet, so fluid flowing from the inlet (2) into the pressure increasing tube (15) is pressurized;

providing a piston (4) which has an inner part (16) and outer part (17 wherein the inner part (16) is secured within an outer part (17),

characterized in that the method further comprises the step of arranging the pressure increasing tube (15) such that at least a portion of the length (L) of the pressure increasing tube (15) is located

within said main spring (5) and such that the pressure increasing tube (15) extends from the inlet (2) to within the inner part (16) of the piston (4).

13. The method according to claim 12 wherein the method comprises the step of arranging the inner part within the outer part, so that the inner part is held by friction within the outer part of the piston.

14. The method according to claim 12 or 13 wherein the method comprises the step of arranging the main spring is to urge the inner part against the outer part, so that the main spring holds the inner part in abutment with the outer part of the piston.

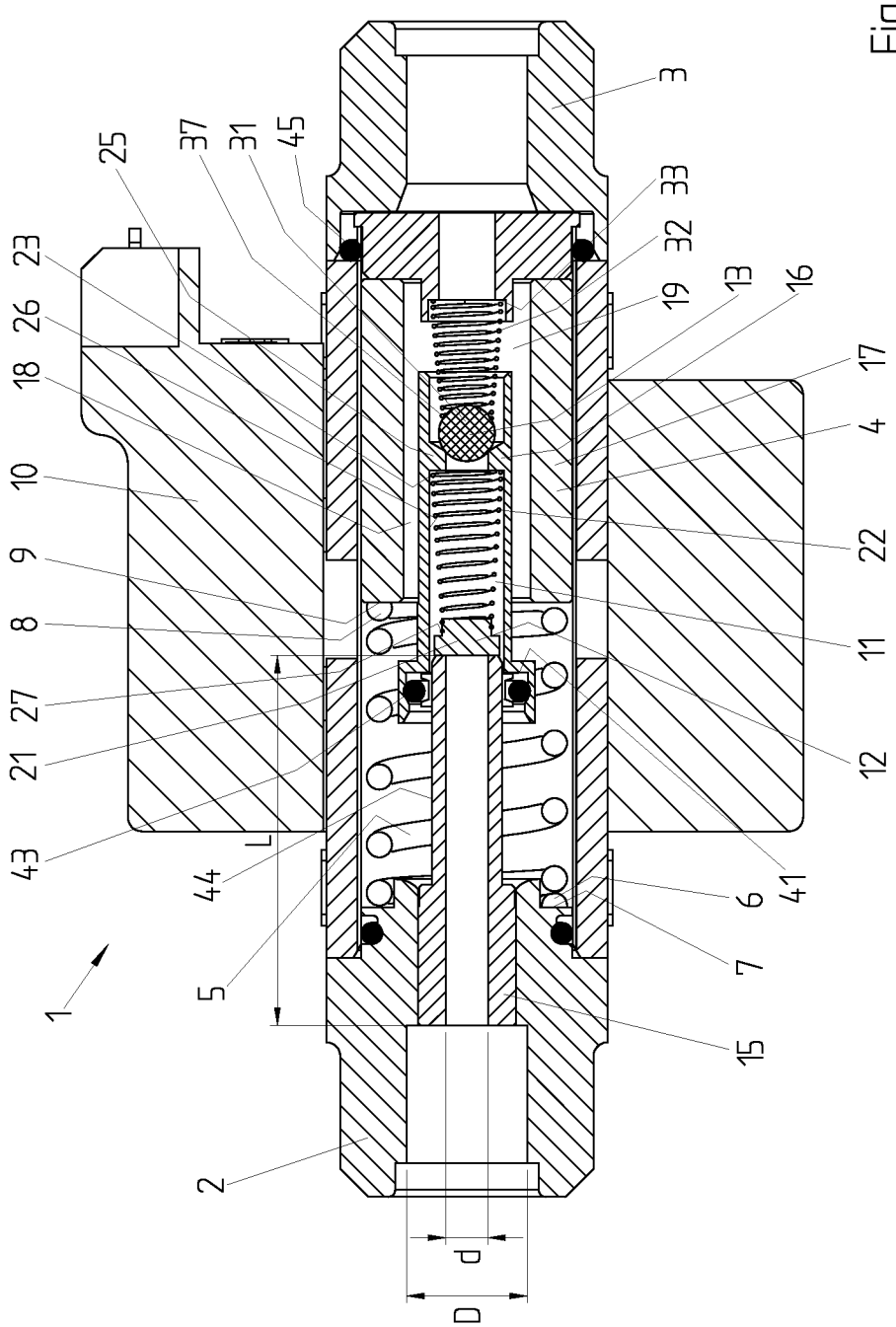

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Fig. 1a

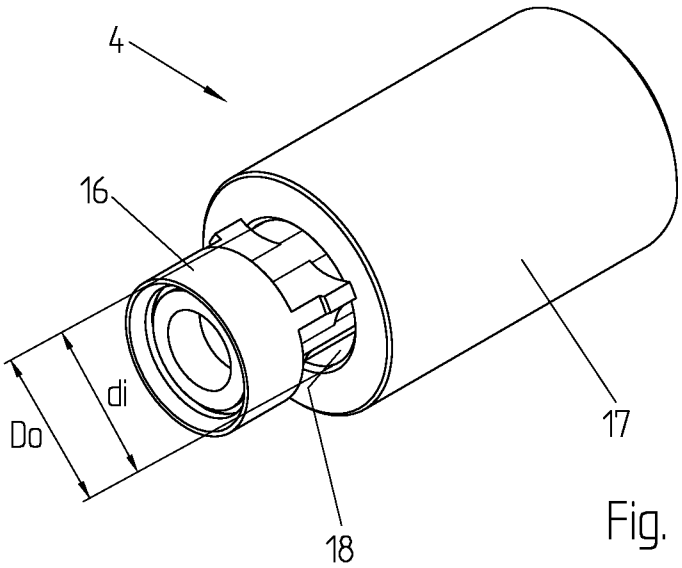


Fig. 1b

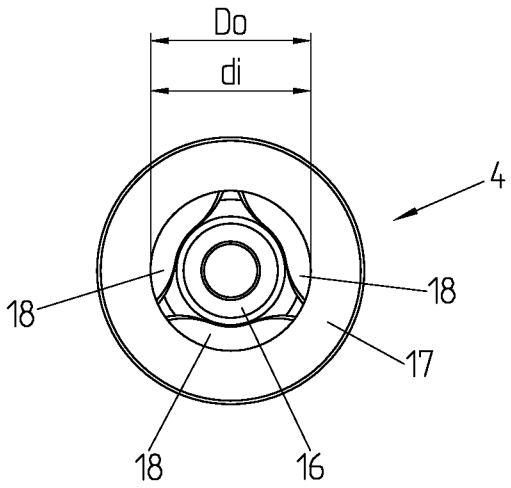
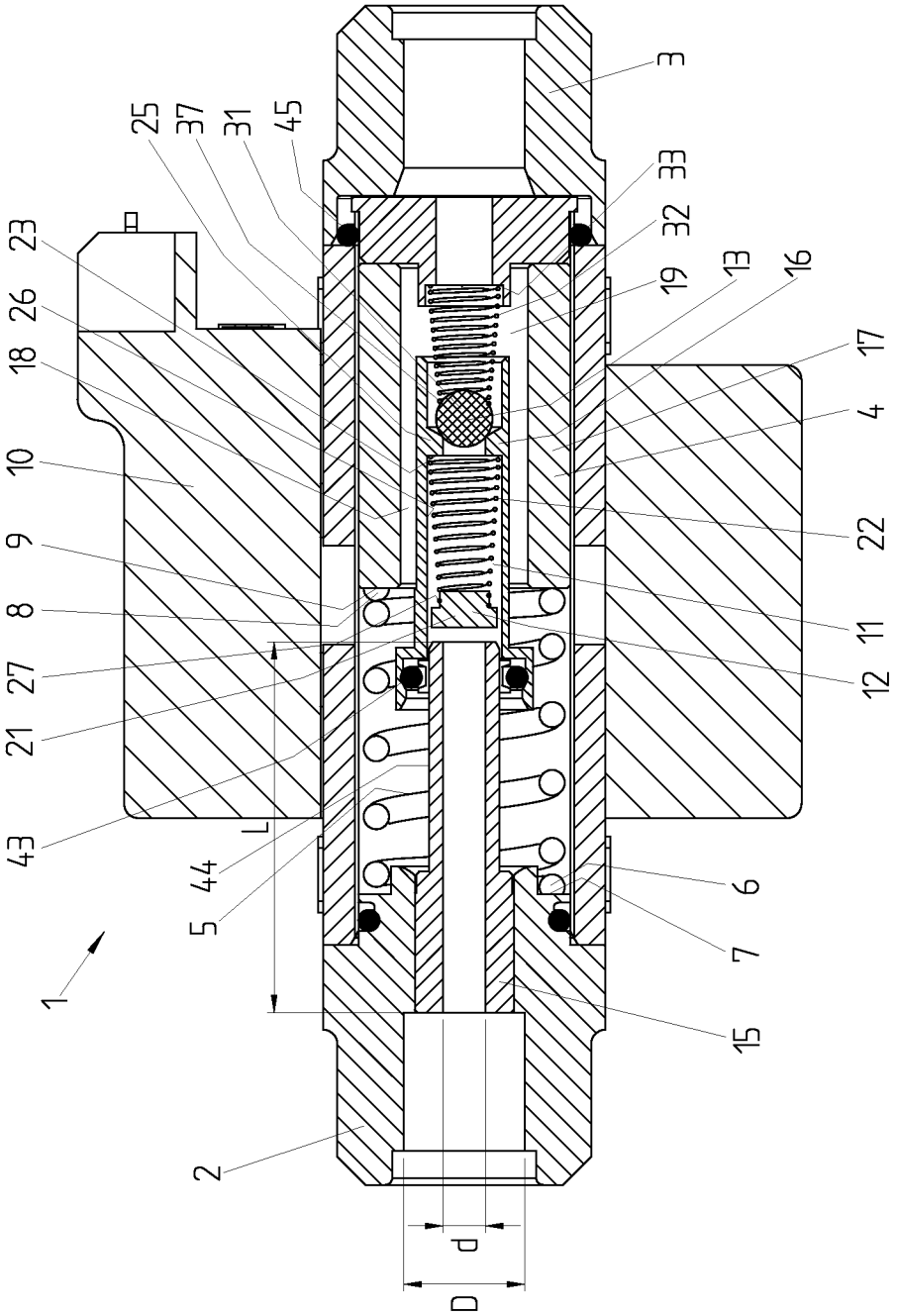


Fig. 1c

Fig. 2


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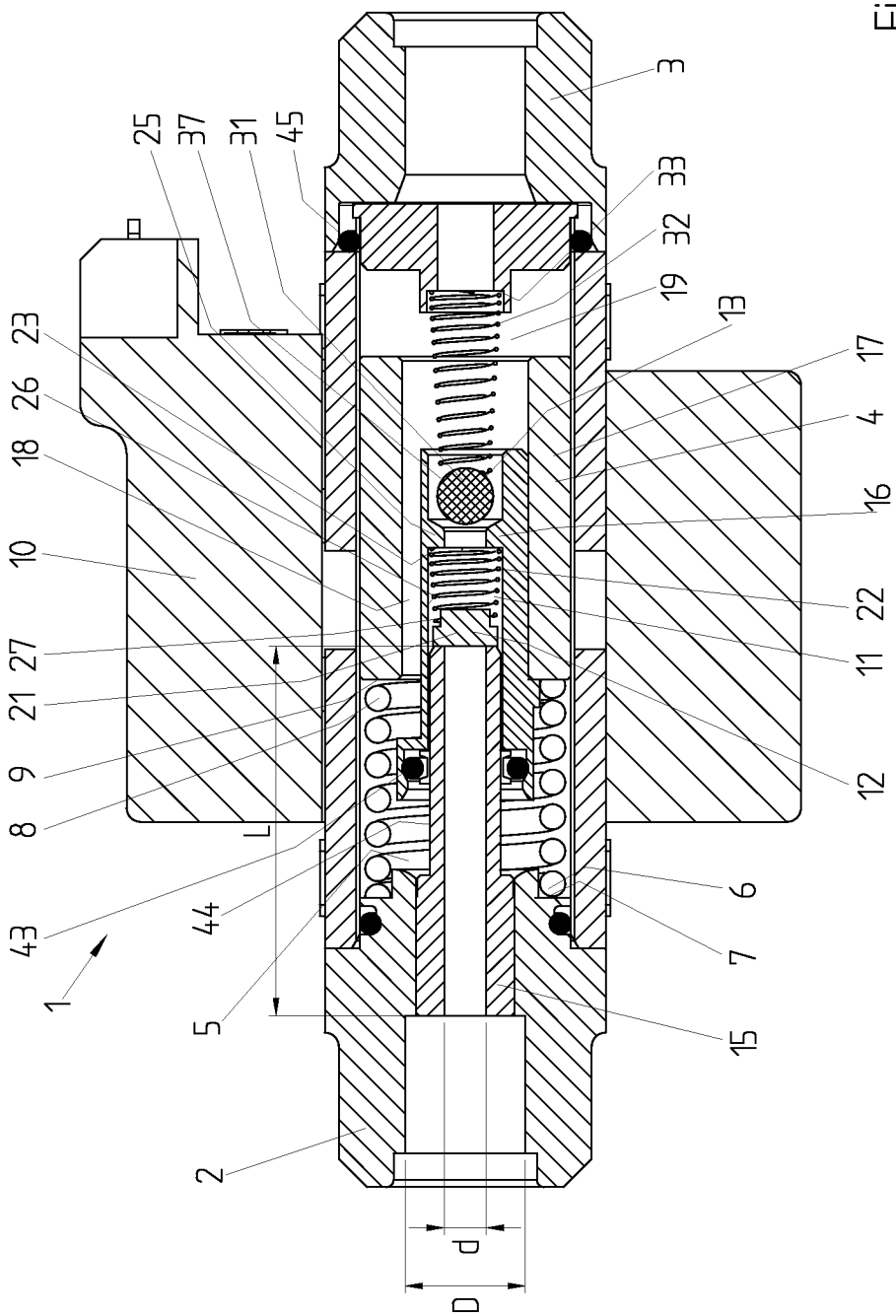

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Fig. 3

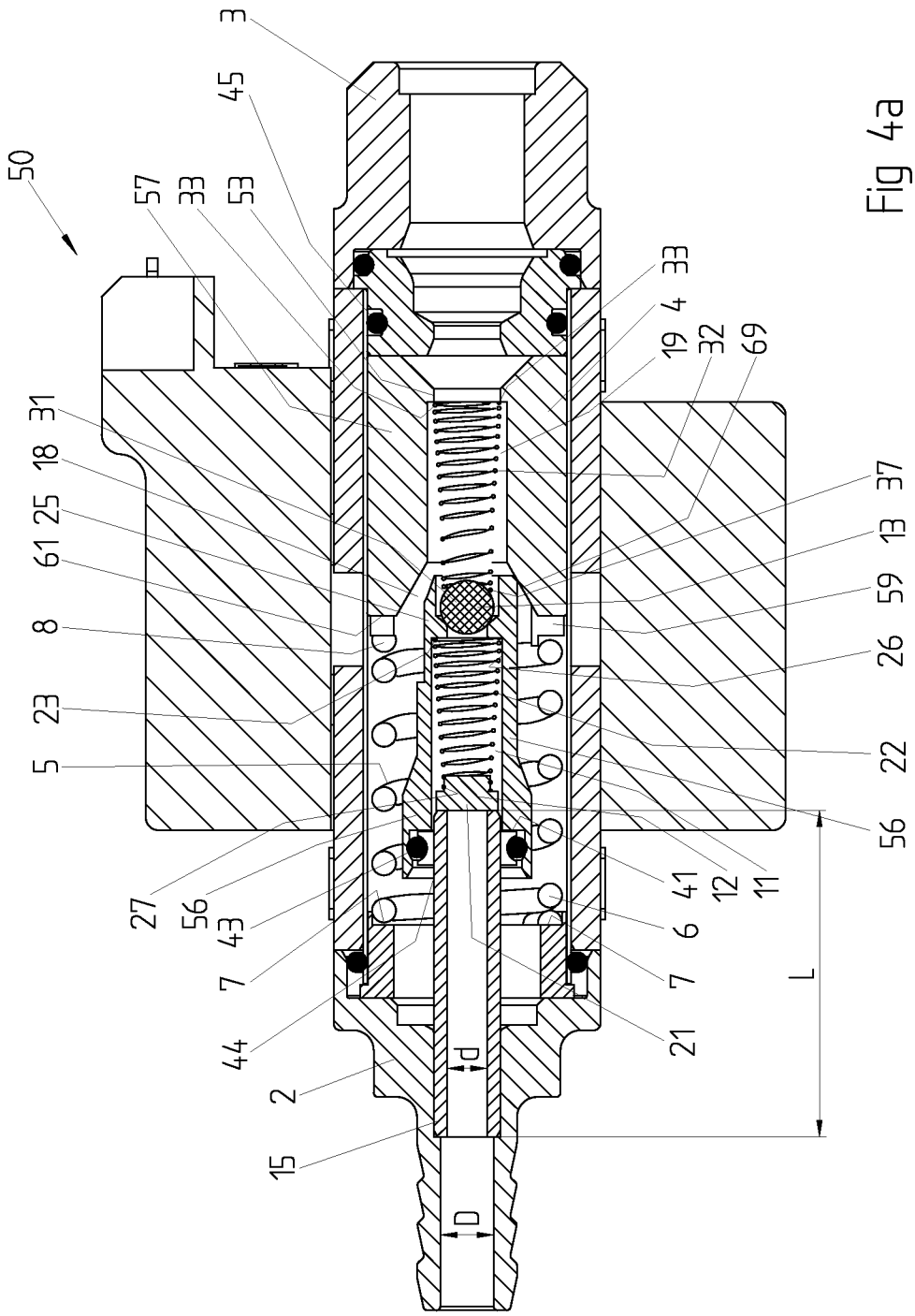

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Fig 4a

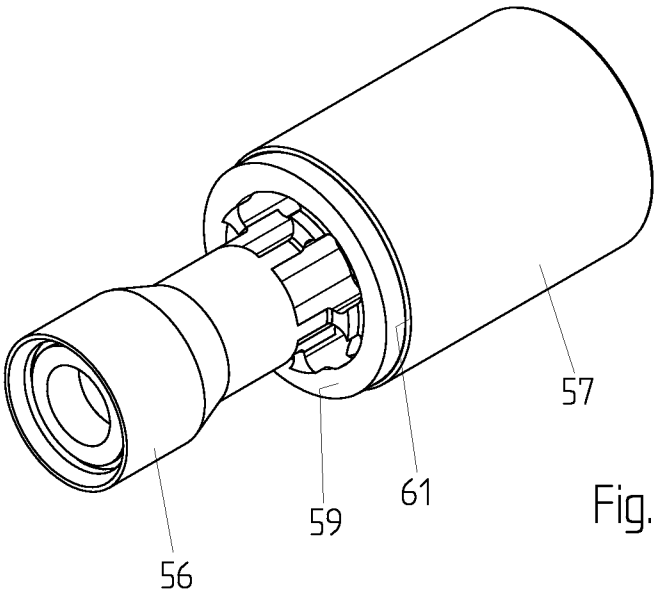


Fig. 4b

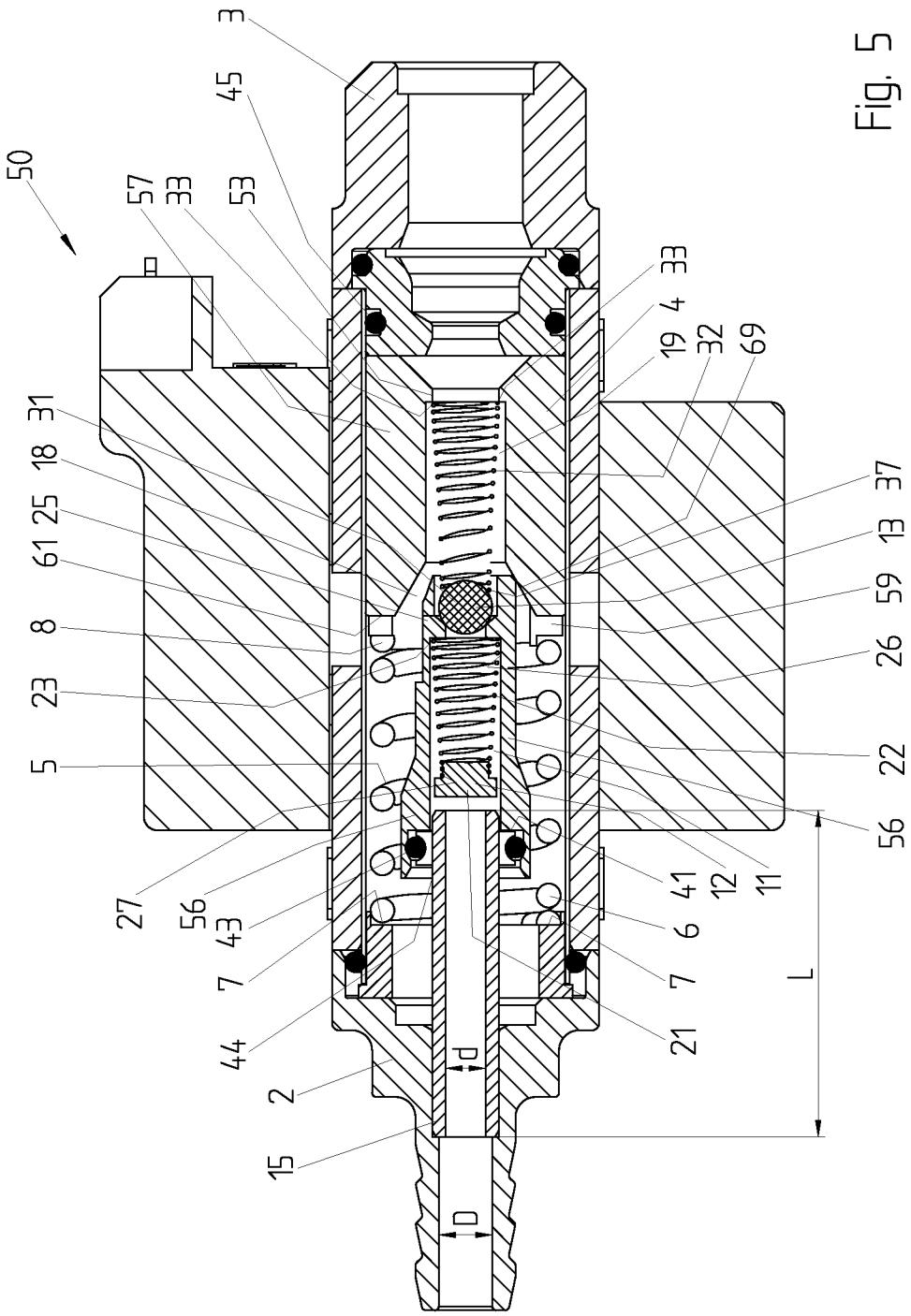

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Fig. 5

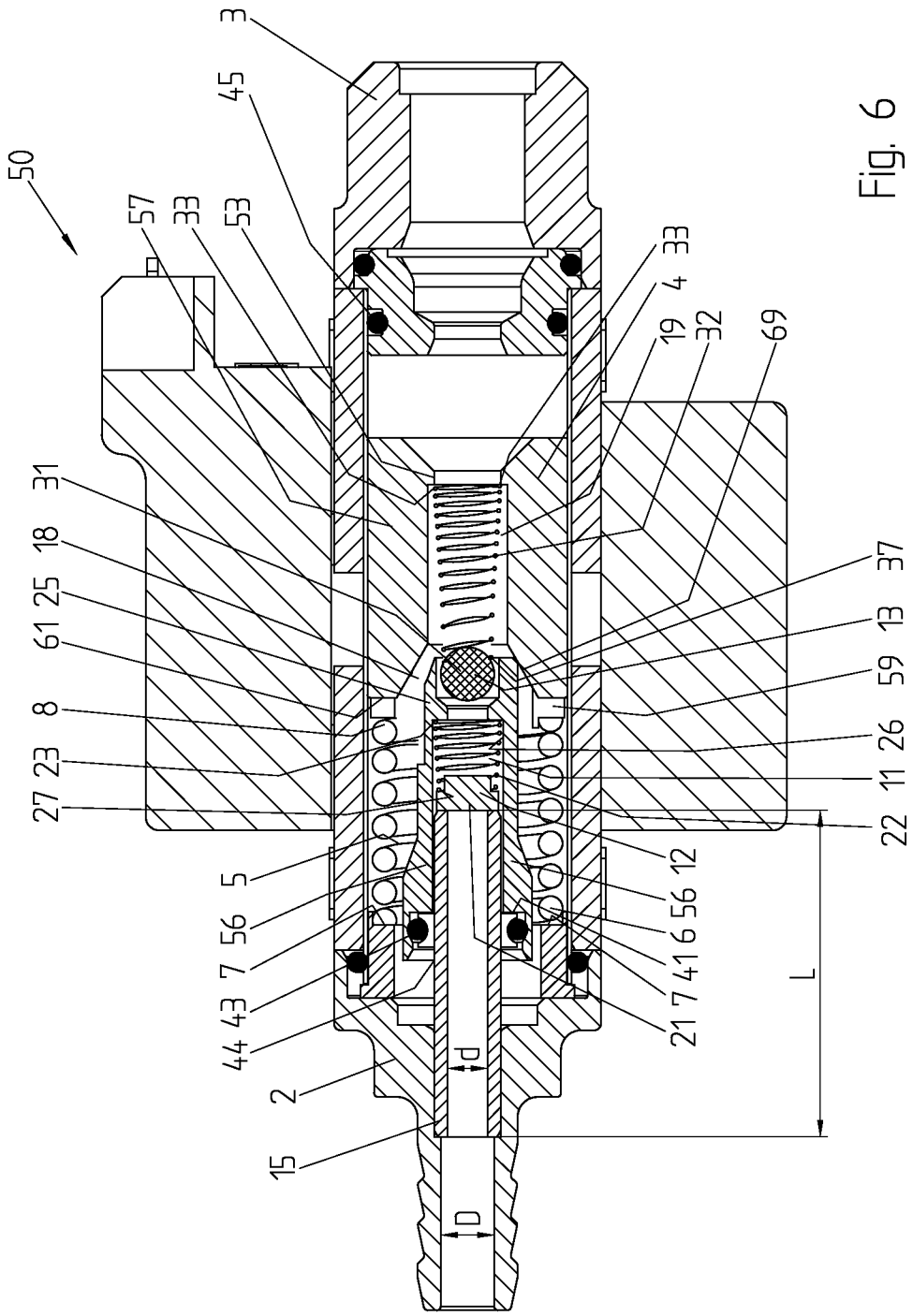

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Fig. 6

Prior Art

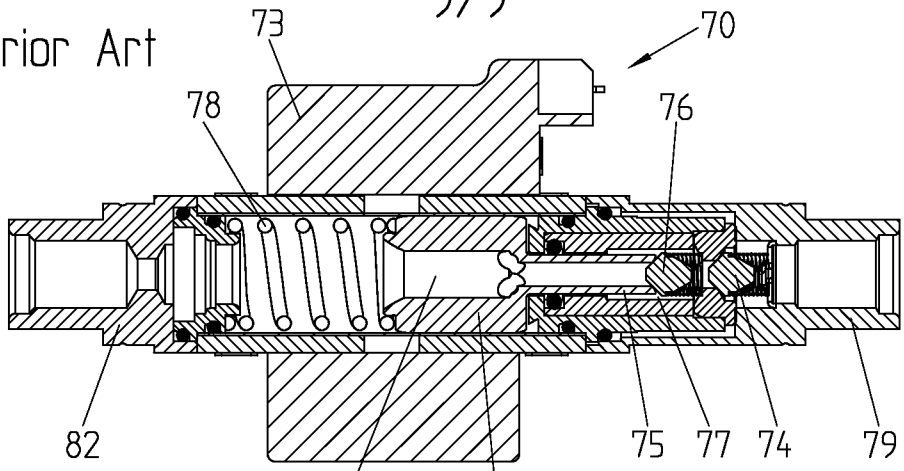


Fig 7a

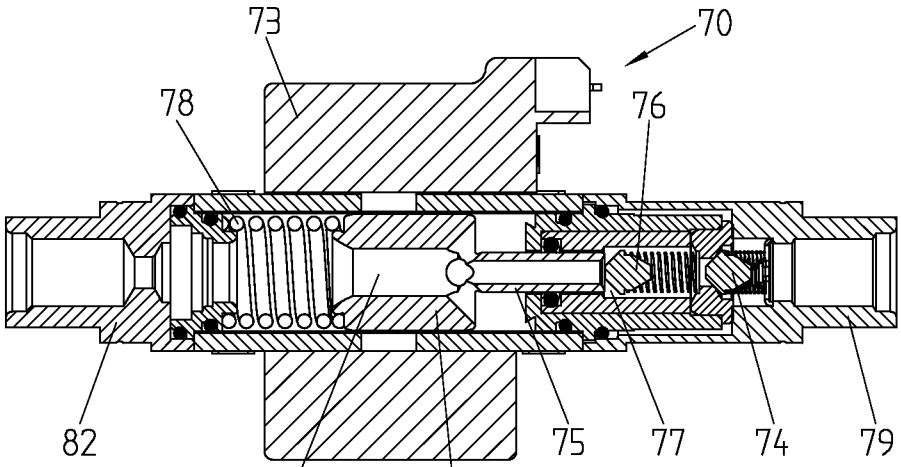


Fig 7b

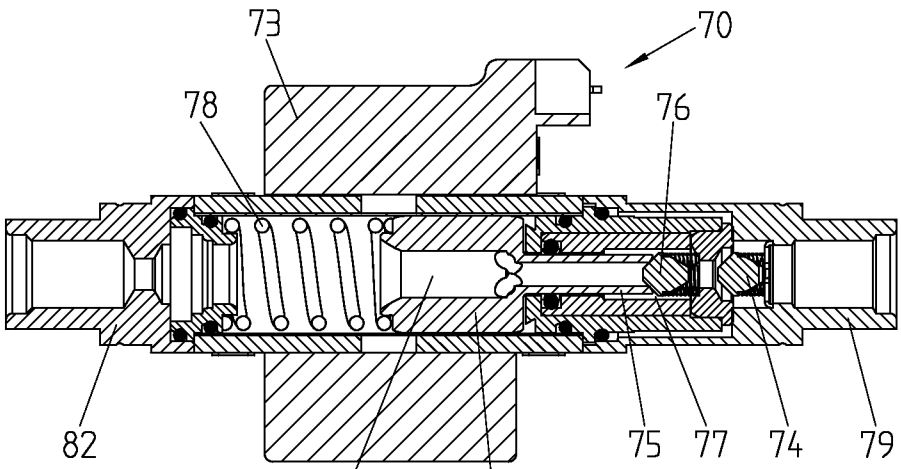


Fig 7c

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2014/058268

A. CLASSIFICATION OF SUBJECT MATTER
INV. F04B17/04 F04B53/12 F04B53/16
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	FR 1 555 291 A (OTTO ECKERLE) 24 January 1969 (1969-01-24) page 1 - page 2; figure 1 -----	1-14
A	DE 24 10 768 A1 (DANFOSS AS) 18 September 1975 (1975-09-18) page 1 - page 9; figures 1,3 -----	1-14

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

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"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
17 June 2014	30/06/2014

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Jurado Orenes, A

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2014/058268

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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