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(54) **GAS EXCHANGE VALVE ARRANGEMENT**

**GASWECHSELVENTILANORDNUNG**

**AGENCEMENT DE SOUPAPE D'ÉCHANGE DE GAZ**

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## Description

### Technical field of the invention

[0001] The present invention relates to a gas exchange valve arrangement for a piston engine in accordance with the preamble of claim 1.

### Background of the invention

[0002] Modern compression ignition piston engines are commonly provided with a supercharger, usually a turbocharger. Turbocharger arrangements are specifically advantageous since they utilize energy of the exhaust gas of the engine. Hereby it is possible to increase the output and efficiency of the engine. In order to minimize emissions from a turbocharged diesel engine, the timing of the intake valves needs to be such that the valves are closed early before bottom dead center of the piston, while the boost pressure is raised accordingly so as to get a sufficient amount of air into the cylinder. However, since the compressors of turbochargers are driven by the exhaust gas turbines, turbochargers tend to be inefficient at low engine loads. With a variable intake valve closing timing (VIC) it is possible to optimize the functioning of the engine. The cam profile can be designed for early intake valve closing, and when needed, the closing timing can be delayed. Delayed closing timing is beneficial especially at low loads, since with an early intake valve closing timing the amount of intake air can be too small. Variable intake valve closing timing, as well as variable exhaust valve closing timing, can be beneficial also in other situations.

[0003] WO 2011/135162 A1 discloses a control arrangement for a gas exchange valve of a piston engine. The arrangement is provided with an electrically controlled valve, which can be used for controlling outflow of hydraulic fluid from a chamber that is arranged between a camshaft and a gas exchange valve. Closing delay of the gas exchange valve can thus be adjusted. However, for achieving different closing speeds of the gas exchange valves, an accurate actuating timing of the electrically controlled valve is needed. Alternatively, the arrangement needs to be provided with a separate throttling device.

### Summary of the invention

[0004] The object of the present invention is to provide an improved gas exchange valve arrangement for a piston engine. The characterizing features of the arrangement according to the invention are given in the characterizing part of claim 1.

[0005] The arrangement according to the invention comprises a camshaft, force transmission means for transforming the rotational motion of the camshaft into a linear motion and transmitting it to a gas exchange valve at least in the opening direction of the gas exchange

valve, a fluid chamber, a piston device which is arranged in the fluid chamber and in force transmission connection with the gas exchange valve, a feed conduit for introducing hydraulic fluid into the fluid chamber during the opening movement of the gas exchange valve, and a control valve for restricting outflow from the fluid chamber for delaying or slowing down the closing movement of the gas exchange valve, the control valve having at least one inlet port, at least one outlet port, and a valve member for opening and closing flow communication between the inlet port and the outlet port. The valve member has at least a first position, in which position maximum flow through the control valve is allowed, a second position, in which position the flow through the control valve is throttled compared to the first position, and a third position, in which position flow through the control valve is prevented.

[0006] With an arrangement according to the invention, different closing delays and closing speeds can be easily provided with a single control valve.

[0007] According to an embodiment of the invention, the control valve is actuated hydraulically. The control valve can comprise one or more pistons for moving the valve member between different positions. According to an embodiment of the invention, the control valve comprises a first piston for moving the valve member between the first position and the second position and a second piston for moving the valve member to the third position.

[0008] According to an embodiment of the invention, the control valve comprises a stopper surface, against which stopper surface the first piston lies when the control valve is switched to the second position. The position of the stopper surface can be adjustable. With an adjustable stopper surface, different gas exchange valve closing speeds can be selected.

[0009] According to another embodiment of the invention, the arrangement is provided with at least two discharge conduits and the inlet port of the control valve is connected to one of the discharge conduits. The two or more discharge conduits can be either branches of a single discharge conduit that is connected to the fluid chamber, or separate conduits that are connected directly to the fluid chamber. With this arrangement, there is no need to move the valve member of the control valve from the third position for allowing closing of the gas exchange valves. The discharge conduit that is not provided with the control valve can comprise, for instance, a throttle that limits outflow from the fluid chamber. When the control valve is in the third position, only one of the discharge conduits is used for emptying the fluid chamber and the gas exchange valves are closed more slowly.

### Brief description of the drawings

[0010] Embodiments of the invention are described below in more detail with reference to the accompanying drawings, in which

Fig. 1 shows a schematic view of a piston engine and a gas exchange valve arrangement,

Fig. 2 shows a control arrangement for gas exchange valves in a phase where the gas exchange valves are closed,

Fig. 3 shows the control arrangement when the closing delay function is in use,

Fig. 4 shows a control valve, which can be used in a control arrangement of figures 2 and 3,

Fig. 5 shows the control valve of figure 4 in a second position,

Fig. 6 shows the control valve of figure 4 in a third position, and

Fig. 7 shows a hydraulic circuit for actuating control valves.

### Description of embodiments of the invention

**[0011]** Figure 1 shows a simplified schematic view of a piston engine 1 as far it is relevant to the understanding of the invention. The engine is a large internal combustion engine, such as a main or an auxiliary engine of a ship or an engine that is used at a power plant for producing electricity. The gas exchange of the cylinders (not shown) in the piston engine 1 is carried out under the control of gas exchange valves 3 located inside a cylinder head 2. The gas exchange valves 3 are operated through a valve mechanism 6 and are driven by the camshaft 4 of the engine and guided by cam profiles 4.1. The rotational motion of the camshaft 4 is transformed into a linear motion and transmitted to the gas exchange valves 3 via force transmission means. In the embodiment of figure 1, the force transmission means comprise a rocker arm 6.1 and a push rod 6.2. However, many other kinds of force transmission arrangements are possible. For instance, the camshaft 4 could be arranged above the gas exchange valves 3. Part of the force transmission means between the camshaft 4 and the gas exchange valves 3 could also be hydraulic. There is a control arrangement 5 between the camshaft 4 and the gas exchange valves 3 for providing delay in the closing of the gas exchange valves 3. Also part of the control arrangement 5 forms part of the force transmission means.

**[0012]** An example of a control arrangement 5 is shown in more detail in figures 2 and 3, of which figure 2 shows it in an inoperative state, whereby the gas exchange valves 3 (not shown) in connection therewith are closed. Figure 3 illustrates a situation, in which the cam profile 4.1 of the camshaft 4 has already started the lift of a piston device 53 of the control arrangement 5 and also the gas exchange valve 3 has started to open. Each cylinder of the engine 1 can be provided with two or more

one intake valves and exhaust valves, and the control arrangement 5 can be used for operating all the intake valves or exhaust valves of one cylinder. The control arrangement 5 comprises a body part 51, which is typically attached to the engine body. The body part 51 is provided with a fluid chamber 52, in which the piston device 53 is arranged. The piston device 53 is movable in the direction of the longitudinal axis of the fluid chamber 52. The camshaft end of the fluid chamber 52 is provided with an end wall 54 comprising a cylindrical opening 55. The piston device 53 comprises a first portion 53.1, the diameter of which corresponds to the diameter of the fluid chamber 52, and a second portion 53.2, the diameter of which corresponds to the diameter of the opening 55 in the end wall 54. The second portion 53.2 of the piston device 53 extends in the body part 51 through the opening 55 into a chamber located on the other side of the end wall 54 of the fluid chamber 52. The thickness of the end wall 54 in the direction of the longitudinal axis of the piston device 53 is dimensioned so as to operate as a guiding element for the second portion 53.2 of the piston device 53. The end wall 54 of the fluid chamber 52 together with the first portion 53.1 of the piston device 53 and the cylindrical walls of the fluid chamber 52 define a chamber space 59, the volume of which increases as the piston device 53 moves in the opening direction of the gas exchange valve 3, i.e. away from the camshaft 4.

**[0013]** On the other side of the end wall 54 of the fluid chamber 52 there is arranged a guide portion 56 as well as a spring 57. The guide portion 56 is provided with a roller 58, which moves along the cam profile 4.1 while the camshaft 4 rotates. The spring 57 is adapted between the guide portion 56 and the end wall 54 to press the guide portion 56 towards the camshaft 4 and to keep the roller 58 in contact with the cam profile 4.1 of the camshaft 4. The fluid chamber 52 is provided with a connection for hydraulic medium, comprising a feed conduit 58.1 and a discharge conduit 58.2, both opening to the chamber space 59. Both conduits 58.1, 58.2 are arranged close to the end wall 54 of the fluid chamber 52 for allowing flow into the chamber space 59 and out of it even when the piston device 53 is at the camshaft end of the fluid chamber 52. The feed conduit 58.1 is in connection with a source 7 of hydraulic medium, which in an engine may also be a normal forced lubrication system. A hydraulic pump 24 supplies hydraulic fluid from the source 7 of hydraulic medium. The feed conduit 58.1 is provided with a shut-off valve 11 and a one-way valve 9. By means of the shut-off valve 11 the feed conduit 58.1 may be connected to the chamber space 59 or disconnected from it, depending on whether the aim is to use the control arrangement for the delayed closing of the gas exchange valve according to the invention or not. Owing to the one-way valve 9 the control arrangement does not cause any pulsations in the source of hydraulic medium. This is of special importance when lubricating oil is used as a hydraulic medium. The discharge conduit 58.2 is divided into a first discharge conduit 58.2a and a second dis-

charge conduit 58.2b. Both the first and the second discharge conduits 58.2a, 58.2b, i.e. the two branches of the discharge conduit 58.2, are in connection with a return system 8 for hydraulic medium, which at simplest may be arranged to open to the inner space of the engine 1, whereby the lubricating oil used as hydraulic medium is allowed to flow down to the oil sump of the engine 1. The second discharge conduit 58.2b is provided with valve means 10 for either preventing flow in the second discharge conduit 58.2b or allowing flow at a certain rate. Instead of being branches of a single discharge conduit 58.2, the first and the second discharge conduits 58.2a, 58.2b could be connected directly to the fluid chamber 52. The first discharge conduit 58.2a is provided with a throttle 60 for throttling outflow from the chamber space 59.

**[0014]** In the situation of figure 3, hydraulic medium, such as lubricating oil, is fed from the source 7 of hydraulic medium through the one-way valve 9 into the chamber space 59, the volume of which increases as the piston device 53 moves in the opening direction of the gas exchange valve 3. Then, the gas exchange valve 3 opens, determined by the shape of the cam profile 4.1, and simultaneously the chamber space 59 is filled with hydraulic medium. Thus, the opening phase of the valve 3 is actuated by an entirely mechanical force transmission connection and the effect of the hydraulic medium will not become apparent until at the closing phase. After the cam profile 4.1 has exceeded its peak, while the camshaft 4 is rotating, the direction of movement of the piston device 53 changes. By utilizing the control valve 10, the route through which the hydraulic medium is released from the chamber space 59 can be selected. The closing delay of the gas exchange valve 3 can thus be affected to comply with the operating conditions of the engine 1.

**[0015]** In figures 4-6 is shown a control valve 10 according to an embodiment of the invention. The control valve 10 is provided with an inlet port 10a, which is connected to the chamber space 59, and with an outlet port 10b, which is connected to the return system 8 for hydraulic medium. The control valve 10 is in the second discharge conduit 58.2b. The control valve 10 comprises a body 12, inside which a movable valve member 13 is arranged. The valve member 13 can be moved to different positions for allowing or preventing outflow from the chamber space 59 of the control arrangement 5. In figure 4, the valve member 13 is in a first position. In this position, the valve member 13 does not throttle the flow between the inlet port 10a and the outlet port 10b and maximum flow through the control valve 10 is thus allowed. Since the hydraulic medium is discharged from the chamber space 59 through both the first discharge conduit 58.2a and the second discharge conduit 58.2b, a short closing delay of the gas exchange valves 3 is provided. Figure 5 shows the control valve 10 in a second position. In this position, the valve member 13 covers approximately half of the cross-sectional area of the inlet port 10a, and flow through the control valve 10 is thus throt-

tled. The closing speed of the gas exchange valves 3 is slower than in the first position of the valve member 13. In figure 6, the valve member 13 is in a third position, in which position the valve member 13 blocks the inlet port 10a. Flow through the control valve 10 is thus prevented. The hydraulic medium is discharged from the chamber space 59 through the first discharge conduit 58.2a only, and the gas exchange valves 3 are closed more slowly.

**[0016]** The control valve 10 is hydraulically actuated and comprises a first piston 17 and a second piston 18 for moving the valve member 13 between the three different positions. Both the first piston 17 and the second piston 18 are coaxial with the valve member 13. The first piston 17 is arranged at the opposite end of the control valve 10 in relation to the valve member 13. The second piston 18 is arranged between the valve member 13 and the first piston 17 and attached to the valve member 13. The first piston 17 can be used for pushing the second piston 18 to the direction of the valve member 13. The control valve 10 is provided with a spring 14, which is arranged around the stem 19 of the second piston 18. The spring 14 pushes the second piston 18 and the valve member 13 attached to it towards the first piston 17 and keeps the valve member 13 in the first position when the control valve 10 is not actuated. The control valve 10 is provided with a first hydraulic connection 15 and with a second hydraulic connection 16. Through the first hydraulic connection 15, hydraulic fluid can be introduced into a first chamber 20, in which the first piston 17 is arranged. As pressurized hydraulic fluid is introduced into the first chamber 20, the first piston 17 moves until it reaches a first stopper surface 22. The position of the first stopper surface 22 can be adjustable for allowing different throttling rates and gas exchange valve closing speeds. The first piston 17 pushes the second piston 18, which moves the valve member 13 into the second position shown in figure 5. Through the second hydraulic connection 16, hydraulic fluid can be introduced into the second chamber 21. As pressurized hydraulic fluid is introduced into the second chamber 21, the second piston 18 moves until it reaches a second stopper surface 23. The movement range of the second piston 18 is greater than the movement range of the first piston 17, and therefore the second piston 18 can push the valve member 13 to the third position shown in figure 6.

**[0017]** In figure 7 is shown a hydraulic circuit, which can be used for actuating control valves 10. The hydraulic circuit is provided with a hydraulic pump 39 for supplying hydraulic fluid into the circuit. The same hydraulic pump 39 could also feed the fluid chambers 52 of the control arrangements 5. The hydraulic circuit comprises a first pipe line 34 for feeding hydraulic fluid into the first chambers 20 of the control valves 10, and with a second pipe line 35 for feeding hydraulic fluid into the second chambers 21 of the control valves 10. The first pipe line 34 is provided with a first actuator valve 30 and the second pipe line 35 is provided with a second actuator valve 31. Both actuator valves 30, 31 are electrically operated 3/2

valves. When the actuator valves 30, 31 are in the positions shown in figure 7, flow from the hydraulic pump 39 to the first and the second chambers 20, 21 of the control valves 10 is prevented and the first chambers 20 and the second chambers 21 are connected to a tank 32. When there is a need to switch the control valves 10 from the first position to the second position, the first actuator valve 30 is switched to another position. The first pipe line 34 is provided with a throttle 36a, which enables pressure build-up in the system. Hydraulic medium is supplied into the first chambers 20 of the control valves 10 and the valve members 13 are moved together with the first pistons 17 to the second position. A pressure sensor 37 is arranged downstream from the first actuator valve 30. When the first pipe line 34 is pressurized, a closing valve 33, which is connected to the first pipe line 34 in parallel with the first chambers 20 of the control valves 10, is closed. The hydraulic medium is thus trapped in the first pipe line 34 between a one-way valve 40, which is located downstream from the first actuator valve 30, and the closing valve 33. The force created by the pressure in the first chambers 20 can thus compensate the force created by the pressure in the chamber spaces 59 of the control arrangement 5.

**[0018]** When the closing valve 33 is opened and the first actuator valve 30 is switched back to the position shown in figure 7, the pressure in the first chambers 20 of the control valves 10 is relieved and the springs 14 push the valve members 13 back to the first position. The control valves 10 are switched to the third position in a similar manner as to the second positions. A smaller pressure is needed for keeping the valve member 13 in the third position, and therefore a closing valve is not needed in the second pipe line 35. Instead, the second pipe line 34 is provided with a throttle 36b, which allows a small pressure increase. A pressure sensor 38 is arranged downstream from the second actuator valve 31 for measuring pressure in the second pipe line 35. When the second actuator valve 31 is switched to another position, hydraulic fluid can flow from the hydraulic pump 39 into the second chambers 21 of the control valves 10. The valve members 13 of the control valves 10 are thus pushed to the third position.

**[0019]** With the gas exchange valve arrangement according to the invention, a suitable closing delay for the gas exchange valves can be easily selected. The control valve with at least three different positions also allows slowing of the closing speed of the gas exchange valves. It will be appreciated by a person skilled in the art that the invention is not limited to the embodiments described above, but may vary within the scope of the appended claims.

## Claims

1. A gas exchange valve arrangement for a piston engine (1), which arrangement comprises a camshaft

(4), force transmission means (6.1, 6.2, 53, 56, 58,) for transforming the rotational motion of the camshaft (4) into a linear motion and transmitting it to a gas exchange valve (3) at least in the opening direction of the gas exchange valve (3), a fluid chamber (52), a piston device (53) which is arranged in the fluid chamber (52) and in force transmission connection with the gas exchange valve (3), a feed conduit (58.1) for introducing hydraulic fluid into the fluid chamber (52) during the opening movement of the gas exchange valve (3), and a control valve (10) for restricting outflow from the fluid chamber (52) for delaying or slowing down the closing movement of the gas exchange valve (3), the control valve (10) having at least one inlet port (10a), at least one outlet port (10b), and a valve member (13) for opening and closing flow communication between the inlet port (10a) and the outlet port (10b), **characterized in that** the valve member (13) has at least a first position, in which position maximum flow through the control valve (10) is allowed, a second position, in which position the flow through the control valve (10) is throttled compared to the first position, and a third position, in which position flow through the control valve (10) is prevented.

2. An arrangement according to claim 1, **characterized in that** the control valve (10) is actuated hydraulically.
3. An arrangement according to claim 1 or 2, **characterized in that** the control valve (10) comprises at least one piston (17, 18) for moving the valve member (13) between different positions.
4. An arrangement according to claim 3, **characterized in that** the control valve (10) comprises a first piston (17) for moving the valve member (13) between the first position and the second position and a second piston (18) for moving the valve member (13) to the third position.
5. An arrangement according to claim 4, **characterized in that** the control valve (10) comprises a stopper surface (22), against which stopper surface (22) the first piston (17) lies when the control valve (10) is switched to the second position.
6. An arrangement according to claim 5, **characterized in that** the position of the stopper surface (22) is adjustable.
7. An arrangement according to any of the preceding claims, **characterized in that** the arrangement is provided with at least two discharge conduits (58.2a, 58.2b) and the inlet port (10a) of the control valve (10) is connected to one of the discharge conduits (58.2a, 58.2b).

## Patentansprüche

1. Gasaustauschventilanordnung für einen Kolbenmotor (1), wobei die Anordnung eine Nockenwelle (4), Kraftübertragungsmittel (6.1, 6.2, 53, 56, 58,) zum Umwandeln der Drehbewegung der Nockenwelle (4) in eine lineare Bewegung und Übertragen dieser auf ein Gasaustauschventil (3) mindestens in der Öffnungsrichtung des Gasaustauschventils (3), eine Fluidkammer (52), eine Kolbenvorrichtung (53), die in der Fluidkammer (52) angeordnet ist und mit dem Gasaustauschventil (3) in Kraftübertragungsverbindung steht, eine Zuführleitung (58.1) zum Einführen von Hydraulikfluid in die Fluidkammer (52) während der Öffnungsbewegung des Gasaustauschventils (3), und ein Steuerventil (10) zum Begrenzen der Ausströmung aus der Fluidkammer (52) zum Verzögern oder Verlangsamen der Schließbewegung des Gasaustauschventils (3), wobei das Steuerventil (10) mindestens eine Einlassöffnung (10a), mindestens eine Auslassöffnung (10b) und ein Ventilelement (13) zum Öffnen und Schließen einer Fluidverbindung zwischen der Einlassöffnung (10a) und der Auslassöffnung (10b) aufweist, **dadurch gekennzeichnet, dass** das Ventilelement (13) mindestens eine erste Position, wobei in dieser Position eine maximale Strömung durch das Steuerventil (10) ermöglicht wird, eine zweite Position, wobei in dieser Position die Strömung durch das Steuerventil (10) im Vergleich zu der ersten Position gedrosselt ist, und eine dritte Position aufweist, wobei in dieser Position die Strömung durch das Steuerventil (10) verhindert wird.
2. Anordnung nach Anspruch 1, **dadurch gekennzeichnet, dass** das Steuerventil (10) hydraulisch betätigt wird.
3. Anordnung nach Anspruch 1 oder 2, **dadurch gekennzeichnet, dass** das Steuerventil (10) mindestens einen Kolben (17, 18) zum Bewegen des Ventilelements (13) zwischen unterschiedlichen Positionen umfasst.
4. Anordnung nach Anspruch 3, **dadurch gekennzeichnet, dass** das Steuerventil (10) einen ersten Kolben (17) zum Bewegen des Ventilelements (13) zwischen der ersten Position und der zweiten Position und einen zweiten Kolben (18) zum Bewegen des Ventilelements (13) an die dritte Position umfasst.
5. Anordnung nach Anspruch 4, **dadurch gekennzeichnet, dass** das Steuerventil (10) eine Anschlagsoberfläche (22) umfasst, wobei der erste Kolben (17) an dieser Anschlagsoberfläche (22) anliegt, wenn das Steuerventil (10) in die zweite Position geschaltet ist.

6. Anordnung nach Anspruch 5, **dadurch gekennzeichnet, dass** die Position der Anschlagsoberfläche (22) einstellbar ist.

7. Anordnung nach einem der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** die Anordnung mit mindestens zwei Ablassleitungen (58.2a, 58.2b) versehen ist und die Einlassöffnung (10a) des Steuerventils (10) mit einer der Ablassleitungen (58.2a, 58.2b) verbunden ist.

## Revendications

1. Ensemble de soupape d'échange de gaz pour un moteur à piston (1), ledit ensemble comprenant un arbre à cames (4), des moyens de transmission de force (6.1, 6.2, 53, 56, 58) destinés à convertir un mouvement de rotation à l'arbre à cames (4) en un mouvement linéaire et à transmettre celui-ci à une soupape d'échange de gaz (3) au moins dans la direction d'ouverture de la soupape d'échange de gaz (3), une chambre à fluide (52), un dispositif à piston (53) disposé dans la chambre à fluide (52) et en liaison de transmission de force avec la soupape d'échange de gaz (3), un conduit d'alimentation (58.1) pour l'introduction de fluide hydraulique dans la chambre à fluide (52) pendant le mouvement d'ouverture de la soupape d'échange de gaz (3), et une soupape de commande (10) destinée à restreindre le flux sortant de la chambre à fluide (52) afin de retarder ou de ralentir le mouvement de fermeture de la soupape d'échange de gaz (3), la soupape de commande (10) présentant au moins un orifice d'entrée (10a), au moins un orifice de sortie (10b), et un élément de soupape (13) pour l'ouverture et la fermeture de la communication fluidique entre l'orifice d'entrée (10a) et l'orifice de sortie (10b), **caractérisé en ce que** l'élément de soupape (13) présente au moins une première position permettant un écoulement maximal à travers la soupape de commande (10), une deuxième position dans laquelle l'écoulement à travers la soupape de commande (10) est étranglé par rapport à la première position, et une troisième position dans laquelle l'écoulement à travers la soupape de commande (10) est empêché.
2. Ensemble selon la revendication 1, **caractérisé en ce que** la soupape de commande (10) est actionnée de façon hydraulique.
3. Ensemble selon la revendication 1 ou 2, **caractérisé en ce que** la soupape de commande (10) comprend au moins un piston (17, 18) pour le déplacement de l'élément de soupape (13) entre différentes positions.
4. Ensemble selon la revendication 3, **caractérisé en**

**ce que** la soupape de commande (10) comprend un premier piston (17) pour le déplacement de l'élément de soupape (13) entre la première position et la deuxième position, et un deuxième piston (18) pour le déplacement de l'élément de soupape (13) vers la troisième position. 5

5. Ensemble selon la revendication 4, **caractérisé en ce que** la soupape de commande (10) comprend une surface d'arrêt (22), le premier piston (17) s'appuyant contre ladite surface d'arrêt (22) lorsque la soupape de commande (10) est commutée vers la deuxième position. 10

6. Ensemble selon la revendication 5, **caractérisé en ce que** la position de la surface d'arrêt (22) est réglable. 15

7. Ensemble selon l'une quelconque des revendications précédentes, **caractérisé en ce que** l'ensemble est pourvu d'au moins deux conduits de décharge (58.2a, 58.2b), et l'orifice d'entrée (10a) de la soupape de commande (10) est relié à l'un des conduits de décharge (58.2a, 58.2b). 20

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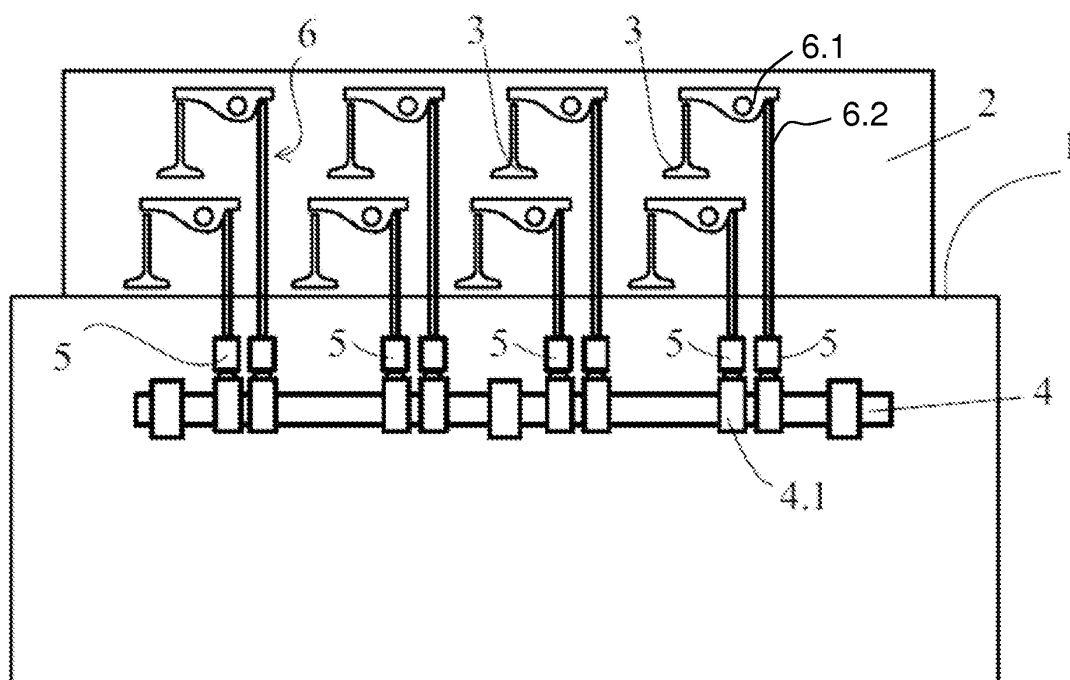


FIG. 1

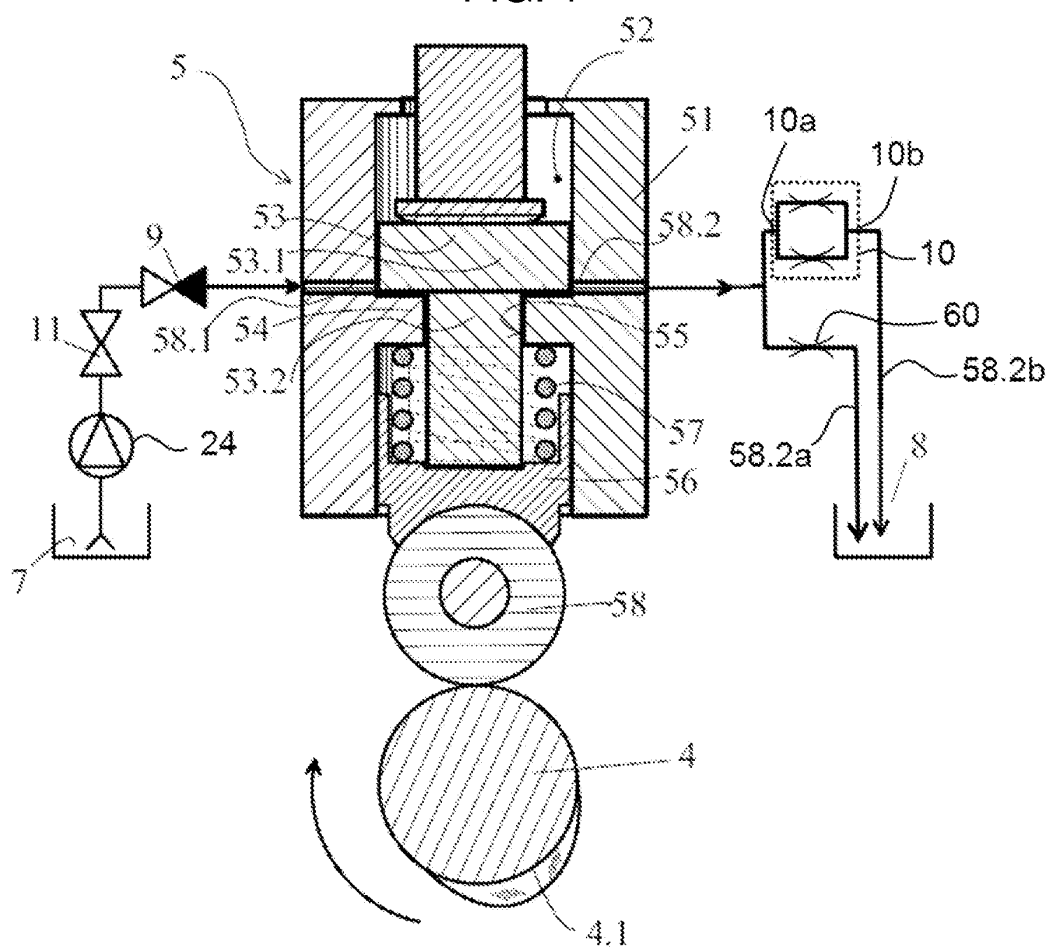


FIG. 2

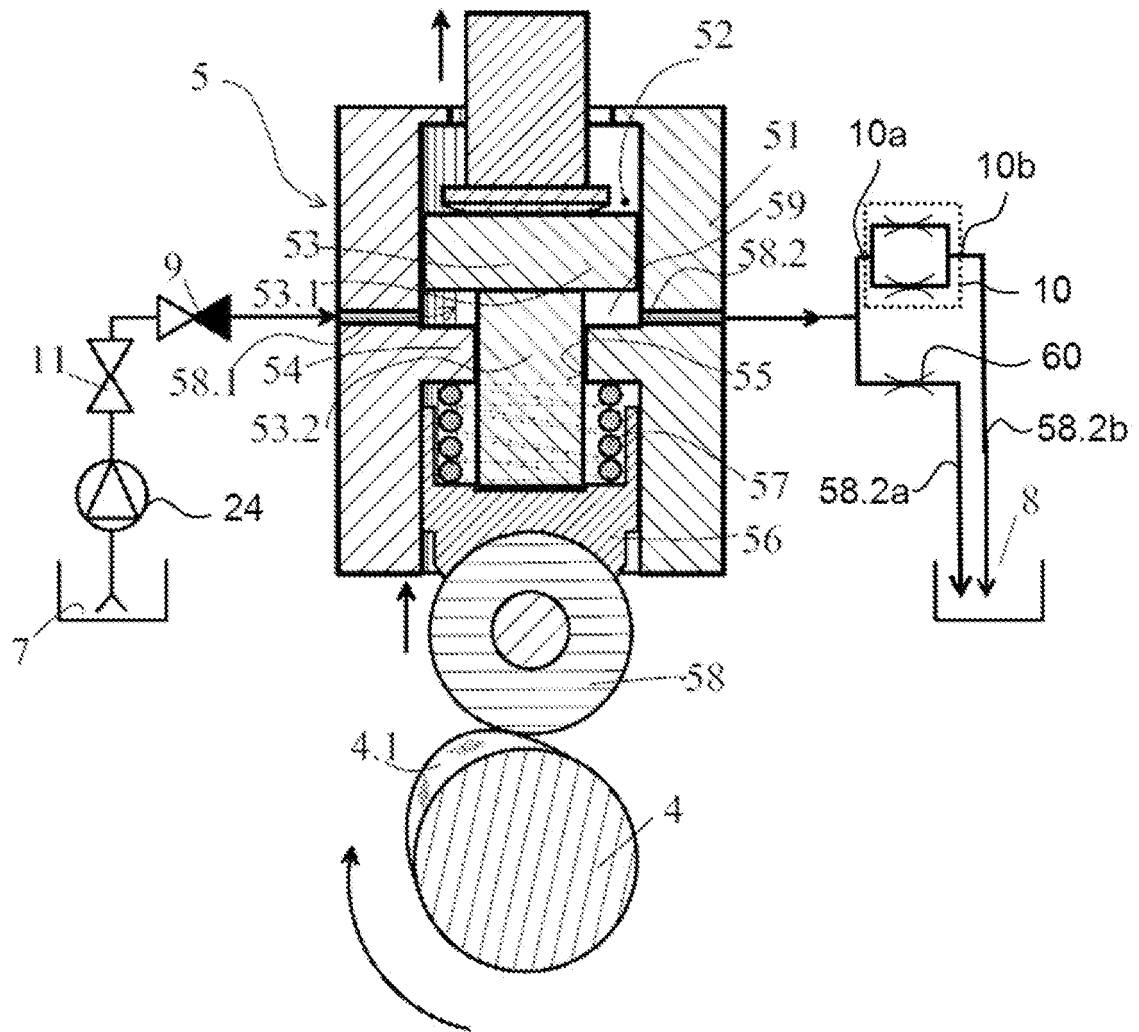


FIG. 3

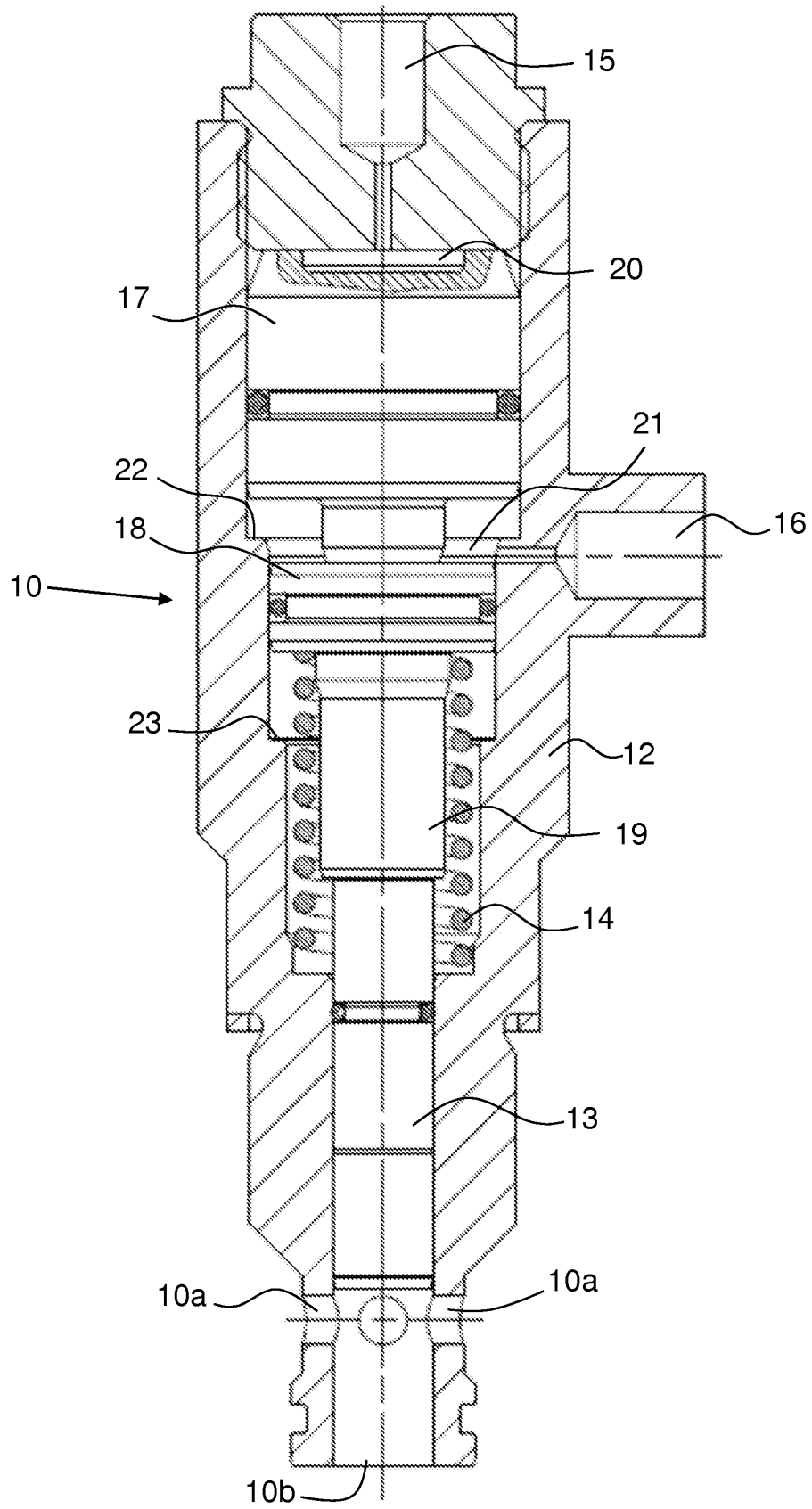


FIG. 4

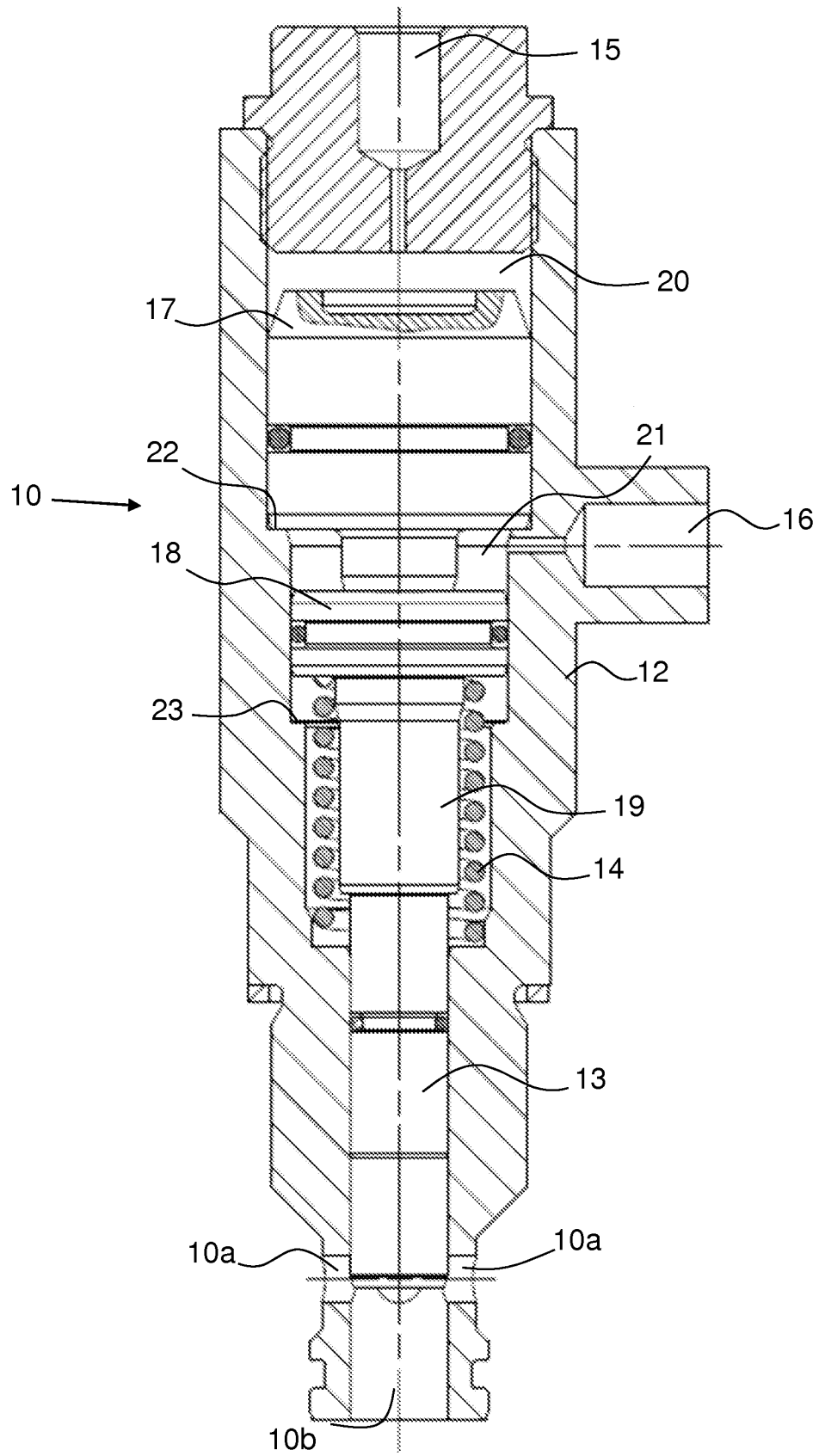


FIG. 5

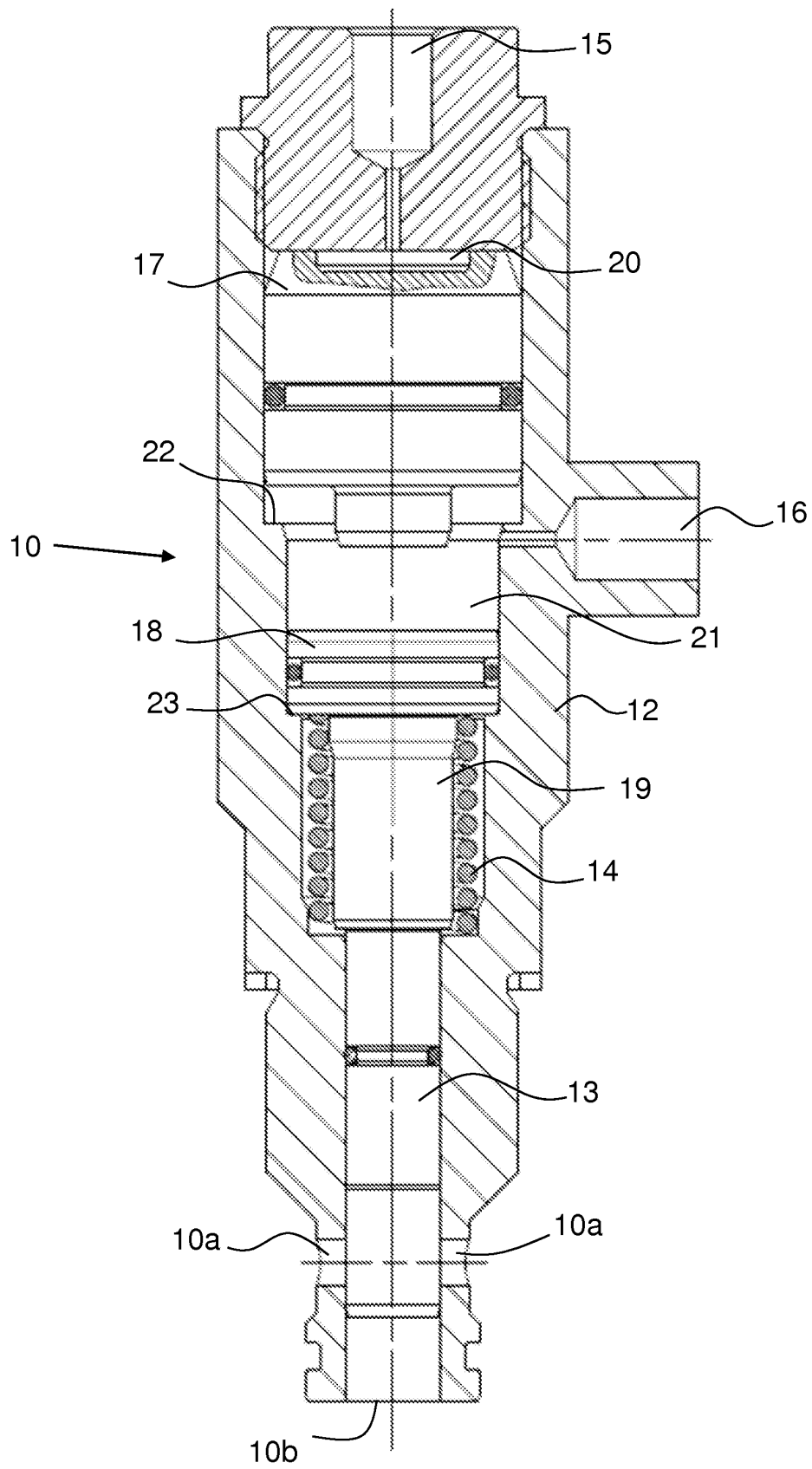


FIG. 6

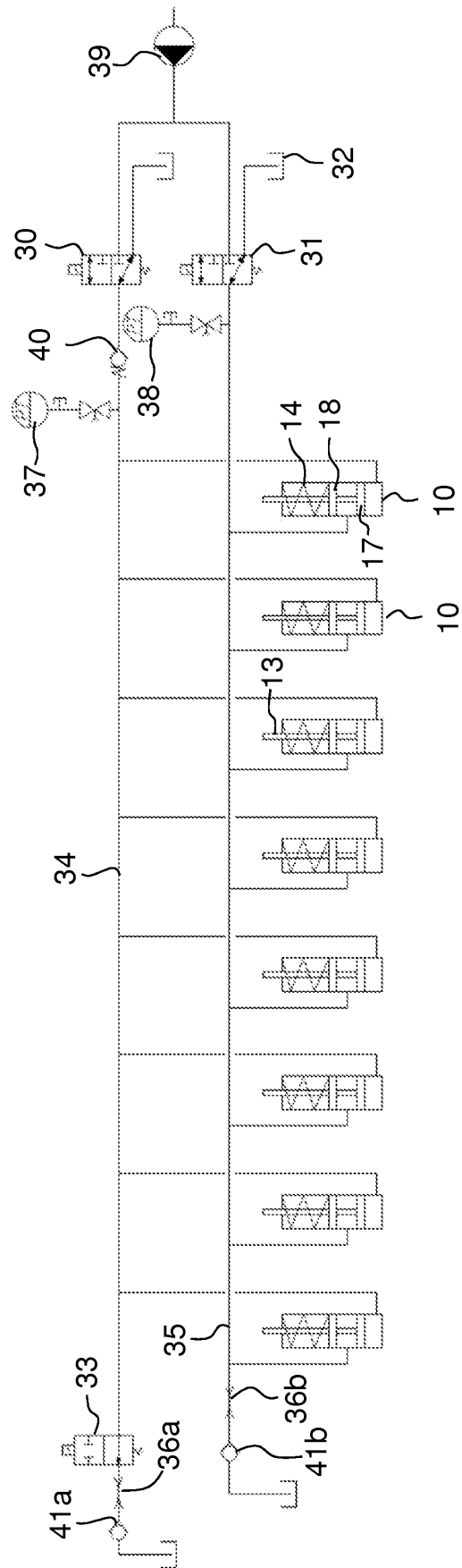


FIG. 7

**REFERENCES CITED IN THE DESCRIPTION**

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**Patent documents cited in the description**

- WO 2011135162 A1 [0003]