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[Continued on next page]

(54) **Title**: VALVE ACTUATOR ARRANGEMENT

(57) **Abstract**: The valve actuator arrangement of an engine comprises a cam-driven piston device (3), which divides a pressurizing chamber (4) into at least two sections (4a, 4b, 4c, 4d) and pressurizes hydraulic fluid in the chamber (4) for opening gas exchange valves (1, 1'). The piston device (3) is used for driving at least one additional valve (9, 10) other than a gas exchange valve (1, 1').

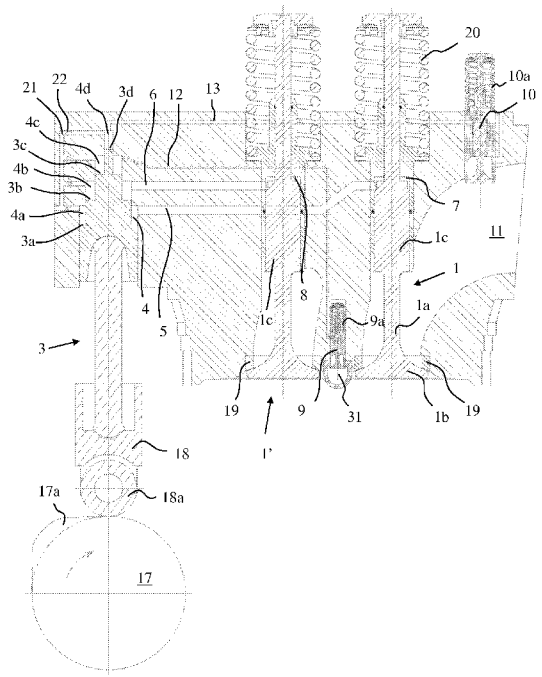

FIG. 1

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— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

VALVE ACTUATOR ARRANGEMENT

Technical field of the invention

The present invention relates to a valve actuator arrangement for an internal combustion engine, as defined in the preamble of claim 1.

Background of the invention

Gas exchange valves of internal combustion engines are most often operated by rotating camshafts, but also hydraulically operated systems are known. Hydraulic valve opening systems are used especially in large internal combustion engines, where they can provide the benefits of variable gas exchange valve opening and closing times. In addition, the components of a hydraulic system can be positioned more freely. However, the reliability of hydraulic systems is not as good as with the mechanical valve actuators. The benefits of both hydraulic and mechanical systems can be combined by using valve actuators, which utilize both hydraulic and mechanical components. For instance, a camshaft can be used for driving a piston, which pressurizes hydraulic fluid for opening gas exchange valves.

Summary of the invention

The object of the present invention is to provide an improved valve actuator arrangement for an internal combustion engine. The characterizing features of the arrangement according to the invention are given in the characterizing part of claim 1.

A valve actuator arrangement according to the invention is arranged to open gas exchange valves of an engine and comprises a pressurizing chamber, a cam-driven piston device, which piston device protrudes into the pressurizing chamber dividing the pressurizing chamber into at least a first section and a second section and comprises a first piston surface for pressurizing hydraulic fluid in the first section of the pressurizing chamber and a second piston surface for pressurizing hydraulic fluid in the second section of the pressurizing chamber, a first hydraulic duct for introducing hydraulic fluid from the first section of the pressurizing chamber to a first receiving chamber for mov-

ing a piston that is connected to a first gas exchange valve, and a second hydraulic duct for introducing hydraulic fluid from the second section of the pressurizing chamber to a second receiving chamber for moving a piston that is connected to a second gas exchange valve. The piston device is used for driving at least one additional valve other than a gas exchange valve.

The valve actuator arrangement combines the reliability of a mechanical actuator system and the adaptability of a hydraulic actuator system. The piston device comprising several piston surfaces divides the flow of the hydraulic fluid equally to the gas exchange valves. Since the same piston device is used for driving also other than gas exchange valves, a compact valve actuator arrangement having several functions is achieved.

The additional valves can be, for instance, gas injection valves, which are used for supplying gaseous fuel to the engine. The engine can comprise a main gas injection valve, which injects fuel into the intake duct, and another gas injection valve, which injects fuel into a pre-chamber.

According to an embodiment of the invention, the piston device divides the pressurizing chamber into an additional third section and comprises a third piston surface for pressurizing hydraulic fluid in the third section of the pressurizing chamber for opening an additional valve. In this embodiment, the piston device is arranged to directly drive an additional valve.

According to another embodiment of the invention, the arrangement comprises a control valve for releasing pressure from a third hydraulic duct, which is arranged between an additional valve and the third section of the pressurizing chamber. With the control valve, the opening and closing timing of the additional valve can be adjusted.

According to another embodiment of the invention, the piston device divides the pressurizing chamber into an additional fourth section and comprises a fourth piston surface for pressurizing hydraulic fluid in the fourth section of the pressurizing chamber for opening an additional valve. According to another embodiment of the invention, the

arrangement comprises a control valve for releasing pressure from a fourth hydraulic duct, which is arranged between an additional valve and the fourth section of the pressurizing chamber. This embodiment is useful in engines comprising for example a prechamber gas injection valve and a main gas injection valve, since both valves can be provided with own piston surfaces and control valves.

According to an embodiment of the invention, the hydraulic duct between the additional valve and the pressurizing chamber is provided with a pressure accumulator. According to another embodiment of the invention, a valve is arranged between the pressure accumulator and the additional valve for selectively introducing hydraulic fluid from the pressure accumulator to the additional valve and for releasing hydraulic fluid from the additional valve. With the pressure accumulator, part of the energy produced by the piston device can be stored, and the opening and closing of the additional valves can be controlled by valves.

According to another embodiment of the invention, a piston that is connected to a gas exchange valve is provided with an additional piston surface facing the opening direction of the gas exchange valve and pressurizing hydraulic fluid for opening an additional valve when the gas exchange valve is opened. In this embodiment, the piston device does not drive the additional valves directly, but the pistons connected to the gas exchange valves are used as pumps.

Brief description of the drawings

Fig. 1 shows a valve actuator arrangement according to a first embodiment of the invention.

Fig. 2 shows a valve actuator arrangement according to a second embodiment of the invention.

Fig. 3 shows a valve actuator arrangement according to a third embodiment of the invention.

Fig. 4 shows a valve actuator arrangement according to a fourth embodiment of the invention.

Fig. 5 shows a valve actuator arrangement according to a fifth embodiment of the invention.

Fig. 6 shows a valve actuator arrangement according to a sixth embodiment of the invention.

Fig. 7 shows a valve actuator arrangement according to a seventh embodiment of the invention.

Fig. 8 shows a valve actuator arrangement according to an eighth embodiment of the invention.

Detailed description of the invention

Embodiments of the invention are now described in more detail with reference to the accompanying drawings.

The valve actuator arrangement according to the invention is used for opening gas exchange valves 1, 1' of an internal combustion engine. The invention is suitable especially for large internal combustion engines, such as main or auxiliary engines of ships or engines that are used at power plants for producing electricity. The valve actuator arrangement comprises a pressurizing chamber 4, in which hydraulic fluid is pressurized by a cam-driven piston device 3 and supplied to the gas exchange valves 1, 1' for opening the valves 1, 1'. In the embodiment of the figures, the gas exchange valves 1, 1' are intake valves, but they could also be exhaust valves. Each of the gas exchange valves 1, 1' comprises a valve stem 1a and a valve disc 1b, which cooperates with a valve seat 19 opening and closing flow communication between the cylinder and the gas exchange duct. In the embodiment of the figures, conventional springs 20 are used for closing the gas exchange valves 1, 1', but also air springs could be used. The piston device 3 is connected to a cam follower unit 18, which comprises a cam follower wheel 18a. The cam follower wheel 18a follows the surface of a rotating cam 17, and when the cam follower wheel 18a becomes engaged with the lobe 17a of the cam 17, the piston device 3 is pushed away from the rotation axis of the cam 17 and protrudes into the pressurizing chamber 3. The piston device 3 divides the pressurizing chamber 4 into two or more sections 4a, 4b, 4c, 4d. A first section 4a of the pressurizing chamber 4 is used for pressurizing hydraulic fluid for opening a first gas exchange valve 1, and a second section

4b of the pressurizing chamber 4 is used for pressurizing hydraulic fluid for opening a second gas exchange valve 1'. The piston device 3 comprises a first piston surface 3a for pressurizing hydraulic fluid in the first section 4a of the pressurizing chamber 4 and a second piston surface 3b for pressurizing hydraulic fluid in the second section 4b of the pressurizing chamber 4. Because of the separate piston surfaces 4a, 4b for the first and the second gas exchange valve 1, 1', the hydraulic fluid is divided equally between the two gas exchange valves 1, 1'. Each of the gas exchange valves 1, 1' is provided with a piston 1c for moving the gas exchange valve 1, 1' in the opening direction of the gas exchange valve 1, 1'. In the embodiment of figure 1, the piston 1c is arranged around the valve stem 1a. The piston 1c of the first gas exchange valve 1 can reciprocate inside a first receiving chamber 7, and the piston 1c of the second gas exchange valve 1' can reciprocate inside a second receiving chamber 8. A first hydraulic duct 5 connects the first receiving chamber 7 to the first section 4a of the pressurizing chamber 4, and a second hydraulic duct 6 connects the second receiving chamber 8 to the second section 4b of the pressurizing chamber 4. When the gas exchange valve 1, 1' is closed, the hydraulic fluid returns via the hydraulic ducts 5, 6 into the pressurizing chamber 4.

In the embodiment of figure 1, the piston device 3 divides the pressurizing chamber 4 into an additional third section 4c and a fourth section 4d. The piston device 3 comprises a third piston surface 3c for pressurizing hydraulic fluid in the third section 4c of the pressurizing chamber 4 and a fourth piston surface 3d for pressurizing hydraulic fluid in the fourth section 4d of the pressurizing chamber 4. Through a third hydraulic duct 12, pressurized hydraulic fluid can be supplied to a first additional valve 9, which is in the embodiment of figure 1 a gas injection valve. The gas injection valve 9 is used for supplying gaseous fuel into a pre-chamber 31. Through a fourth hydraulic duct 13, pressurized hydraulic fluid can be supplied from the fourth section 4d of the pressurizing chamber 4 to a second additional valve 10, which is in the embodiment of figure 1 a main gas injection valve 10, which can be used for supplying gaseous fuel into the intake duct 11 of the engine. Both gas injection valves 9, 10 are provided with a valve spring 9a, 10a, which closes the valve 9, 10 when pressure is relieved from the valve 9, 10. When the gas injection valves 9, 10 are closed, the hydraulic fluid returns via the hydraulic ducts 12, 13 back into the pressurizing chamber 4. Since the same piston device 3 is used for operating both the intake valves 1, 1' and the additional valves 9, 10,

which are not gas exchange valves, the same compact arrangement includes several functions. For compensating leakages from the system, the arrangement is provided with an inlet duct 21 for supplying hydraulic fluid into the pressurizing chamber 4. Each of the sections 4a, 4b, 4c, 4d of the pressurizing chamber 4 is provided with an own branch of the inlet duct 21 and with a check valve 22 for preventing flow from the pressurizing chamber 4 into the inlet duct 21.

The embodiment of figure 2 is similar to the embodiment of figure 1, and therefore only the differences between the embodiments are described. The difference between the two embodiments is that in figure 2, each of the third hydraulic duct 12 and the fourth hydraulic duct 13 is provided with a branch 12a, 13a. The branch 12a, 13a is provided with a control valve 14, 14', which has an open position and a closed position. The control valve 14, 14' can be, for instance, a solenoid valve. When the control valve 14, 14' is closed, the arrangement works in the same manner as in the embodiment of figure 1. When the control valve 14 is open, pressure building in the hydraulic duct 12, 13 is prevented, or if the hydraulic fluid in the duct 12, 13 is pressurized, the pressure is relieved. By opening the control valve 14, 14', the gas injection valve 9, 10 can thus be closed before the cam follower wheel 18a leaves the lobe 17a of the cam 17. If the control valve 14, 14' is kept open when the cam follower wheel 18a enters the lobe 17a of the cam 17 and the movement of the piston device 3 begins, the opening of the gas injection valves 9, 10 can be delayed. The gas injection valves 9, 10 do not start opening until the valve 14, 14' is closed.

Also the embodiment of figure 3 is similar to the embodiment of figure 1. The opening of the main gas injection valve 10 that is located in the intake duct 11 works in the same manner as in the embodiment of figure 1. The third hydraulic duct 12 is provided with a branch 12a, and a pressure accumulator 15 is arranged at the end of the branch 12a. There is also a check valve 23 in the third hydraulic duct 12 between the pressurizing chamber 4 and the branch 12a. The hydraulic duct 12 is further provided with a three-way valve 24, which is arranged downstream from the pressure accumulator 15. In a first position of the three-way valve 24, flow from the pressure accumulator 15 to the gas injection valve 9 is allowed. In a second position of the three-way valve 24, flow from the gas injection valve 9 into a tank is allowed. With the three-way valve 24, both

the opening and closing timing of the gas injection valve 9 can be adjusted. An additional difference to the other embodiments is that the arrangement comprises means 25, 26 for variable intake closing (VIC). Between the cam follower unit 18 and the piston device 3 there is a chamber 25 and a piston 26. By introducing hydraulic fluid into the chamber 25, the return stroke of the piston device 3 and the closing of the gas exchange valves 1, 1' can be delayed.

The embodiment of figure 4 is similar to the embodiment of figure 3. In this embodiment, the piston device 3 is provided with only three piston surfaces 3a, 3b, 3c. The third piston surface 3c is used for operating two gas injection valves 9, 10. The fourth hydraulic duct 13 is branched from the third hydraulic duct 12. Also in this embodiment, the second hydraulic duct 12 is provided with a branch 12a and a pressure accumulator 15 is arranged at the end of the branch 12. Between the branch 12a and the pressurizing chamber 4 there is a check valve 23. The second hydraulic duct 12 is provided with three-way valve 24, which works in the same manner as in the embodiment of figure 3. The fourth hydraulic duct 13 branches from the second hydraulic duct 12 upstream from the three-way valve 24, i.e. between the pressure accumulator 15 and the three way valve 24. Also the fourth hydraulic duct 13 is provided with a three-way valve 24', which works in the same manner as the valve 24 in the third hydraulic duct 12. The opening and closing timings of both gas injection valves 9, 10 can thus be adjusted in the same manner by switching between the two positions of the three-way valves 24, 24'.

The embodiment of figure 5 is similar to the embodiment of figure 3. The only differences are that instead of being connected to the third hydraulic duct 12, the pressure accumulator 15 and the three-way valve 24 are connected to the fourth hydraulic duct 13, and the arrangement is not provided with VIC. The three-way valve 24 is thus used for adjusting the opening and closing timing of the gas injection valve 10 that is located in the intake duct 11. The gas injection valve 9 of the pre-chamber 31 works in the same manner as in the embodiment of figure 1.

In the embodiment of figure 6, the main gas injection valve 10 is controlled in the same way as in the embodiment of figure 2, i.e. the fourth hydraulic duct 13 is provided with

a control valve 14, through which the pressure from the duct 13 can be relieved. The third hydraulic duct 12 is provided with a branch 12a. The branch 12a is connected to a chamber 27, which is provided with a spring-loaded piston 28. The piston 28 has a limited moving range. The stiffness of the spring 29 is chosen so that when the pressure in the third hydraulic duct 12 increases, the piston 28 in the chamber 29 moves over its full moving range before the gas injection valve 9 of the pre-chamber 31 opens. The opening of the gas exchange valve 9 is thus delayed compared to an arrangement without the spring-loaded piston 28.

In the embodiment of figure 7, the piston device 3 is provided only with the first piston surface 3a and the second piston surface 3b. Accordingly, the pressurizing chamber 4 is divided into a first section 4a and a second section 4b. The gas exchange valves 1, 1' are controlled in the same manner as in the other embodiments of the invention. However, the piston 1c that is used for moving each gas exchange valve 1, 1' has been arranged at the end of the valve stem 1a. The piston 1c is provided with a second piston surface 16 that is facing the opening direction of the gas exchange valve 1, 1'. The gas injection valves 9, 10 are operated by hydraulic fluid that is pressurized by the second piston surfaces 16 of the pistons 1c that are in connection with the gas exchange valve 1, 1'. The piston 1c divides the receiving chamber 7, 8 into an input section 7a, 8a and an output section 7b, 8b. The third hydraulic duct 12 and the fourth hydraulic duct 13 have been arranged between the gas injection valves 9, 10 and the output sections 7b, 8b of the receiving chambers 7, 8. An inlet duct 30 is connected to the output section 7b, 8b of each receiving chamber 7, 8 for compensating leakages from the system. The inlet duct 30 is connected to the output section 8b of the receiving chamber 8 of the second gas exchange valve 1' at such a height that the opening of the gas injection valve 9 of the pre-chamber 31 does not start simultaneously with the opening of the second gas exchange valve 1', but only after approximately half of the full opening movement of the second gas exchange valve 1'. Until that, the hydraulic fluid flows from the output section 8b of the receiving chamber 8 back into the inlet duct 30.

In the embodiment of figure 8, the piston 1c of the second gas exchange valve 1' is used for operating the gas injection valve 9 that is in the pre-chamber 31 in the same manner as in the embodiment of figure 7. For operating the main gas injection valve 10 in the

intake duct 11, the piston device 3 is provided with a third piston surface 3c. A third hydraulic duct 12 connecting a third section 4c of the pressurizing chamber 4 to the gas injection valve 10 is provided with a branch 12a. A pressure accumulator 15 is arranged at the end of the branch 12a. There is also a check valve 23 in the hydraulic duct 12 before the branch 12a, and a three-way valve 24 that is arranged after the branch 12a. The control of the gas injection valve 10 in the intake duct 11 works thus in the same manner as in the embodiment of figure 5. When the three-way valve 24 allows flow from the pressure accumulator 15 to the gas injection valve 10, the gas injection valve 10 is opened. When the hydraulic fluid is released via the three-way valve 24 from the gas injection valve 24 into a tank, the gas injection valve 10 is closed. The hydraulic fluid flowing past the piston 15a of the pressure accumulator 15 is utilized by connecting the backside of the piston 15a to a duct 30 that is connected to the output section 8b of the receiving chamber 8 of the second gas exchange valve 1' and works as the inlet duct 30, through which the leakages of the system are compensated.

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. For instance, the features of the embodiments shown in different figures can be combined in different ways. Each cylinder of the engine can be provided with several pre-chambers, each of the pre-chambers having one or more gas injection valves, and the actuator can be used for operating all the valves. Also, there can be more than one gas-injection valve in the intake duct of each cylinder of the engine. If the number of the valves is larger than in the embodiments of the figures, the number of the sections in the pressurizing chamber can be increased accordingly.

Claims

1. A valve actuator arrangement for an internal combustion engine, which valve actuator arrangement is arranged to open gas exchange valves (1, 1') of an engine and comprises

- a pressurizing chamber (4),
- a cam-driven piston device (3), which piston device (3) protrudes into the pressurizing chamber (4) dividing the pressurizing chamber (4) into at least a first section (4a) and a second section (4b) and comprises a first piston surface (3a) for pressurizing hydraulic fluid in the first section (4a) of the pressurizing chamber (4) and a second piston surface (3b) for pressurizing hydraulic fluid in the second section (4b) of the pressurizing chamber (4),
- a first hydraulic duct (5) for introducing hydraulic fluid from the first section (4a) of the pressurizing chamber (4) to a first receiving chamber (7) for moving a piston (1c) that is connected to a first gas exchange valve (1), and
- a second hydraulic duct (6) for introducing hydraulic fluid from the second section (4b) of the pressurizing chamber (4) to a second receiving chamber (8) for moving a piston (1c) that is connected to a second gas exchange valve (1'),

characterized in that the piston device (3) is used for driving at least one additional valve (9, 10) other than a gas exchange valve (1, 1').

2. An arrangement according to claim 1, **characterized** in that the additional valve is a gas injection valve (10) that is arranged to supply gaseous fuel into the intake duct (11) of the engine.

3. An arrangement according to claim 1 or 2, **characterized** in that the additional valve is a gas injection valve (9) that is arranged to supply gaseous fuel into a prechamber (31).

4. An arrangement according to any of claims 1–3, **characterized** in that the piston device (3) divides the pressurizing chamber (4) into an additional third section (4c) and comprises a third piston surface (3c) for pressurizing hydraulic fluid in the third section (4c) of the pressurizing chamber (4) for opening an additional valve (9, 10).

5. An arrangement according to claim 4, **characterized** in that the arrangement comprises a control valve (14) for releasing pressure from a third hydraulic duct (12), which is arranged between an additional valve (9, 10) and the third section (4c) of the pressurizing chamber (4).

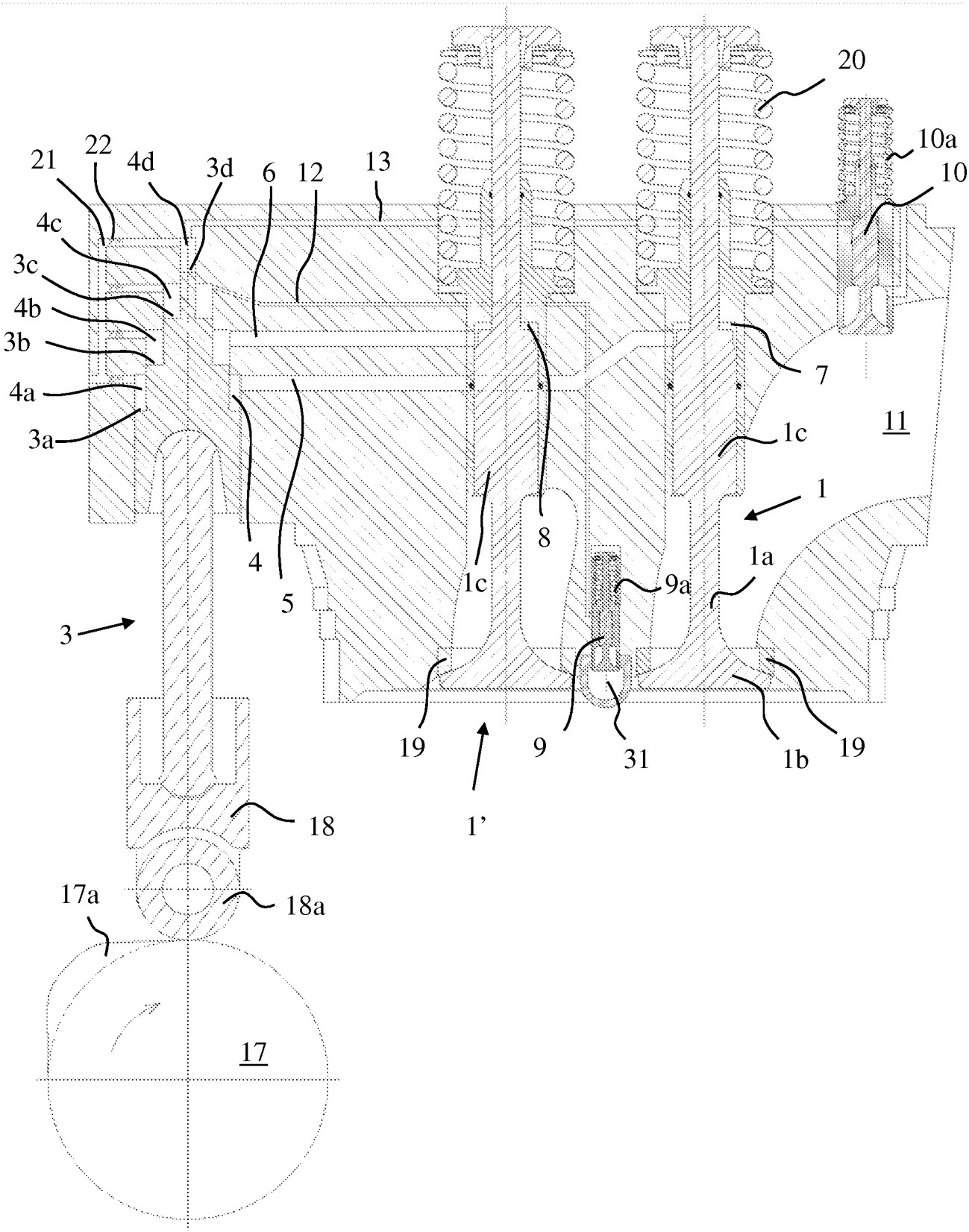
6. An arrangement according to claim 4 or 5, **characterized** in that the piston device (3) divides the pressurizing chamber (4) into an additional fourth section (4d) and comprises a fourth piston surface (3d) for pressurizing hydraulic fluid in the fourth section (4d) of the pressurizing chamber (4) for opening an additional valve (9, 10).

7. An arrangement according to claim 6, **characterized** in that the arrangement comprises a control valve (14') for releasing pressure from a fourth hydraulic duct (13), which is arranged between an additional valve (9, 10) and the fourth section (4d) of the pressurizing chamber (4).

8. An arrangement according to any of claims 4–7, **characterized** in that the hydraulic duct (12, 13) between the additional valve (9, 10) and the pressurizing chamber (4) is provided with a pressure accumulator (15).

9. An arrangement according to claim 8, **characterized** in that a valve (24, 24') is arranged between the pressure accumulator (15) and the additional valve (9, 10) for selectively introducing hydraulic fluid from the pressure accumulator (15) to the additional valve (9, 10) and for releasing hydraulic fluid from the additional valve (9, 10).

10. An arrangement according to any of the preceding claims, **characterized** in that a piston (1c) that is connected to a gas exchange valve (1, 1') is provided with an additional piston surface (16) facing the opening direction of the gas exchange valve (1, 1') and pressurizing hydraulic fluid for opening an additional valve (9, 10) when the gas exchange valve (1, 1') is opened.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4b
3b
4a
3a
7
11
1c
1
8
4
5
1c
9a
1a
3
19
9
31
1b
19
1'
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17a
18a
17

FIG. 1

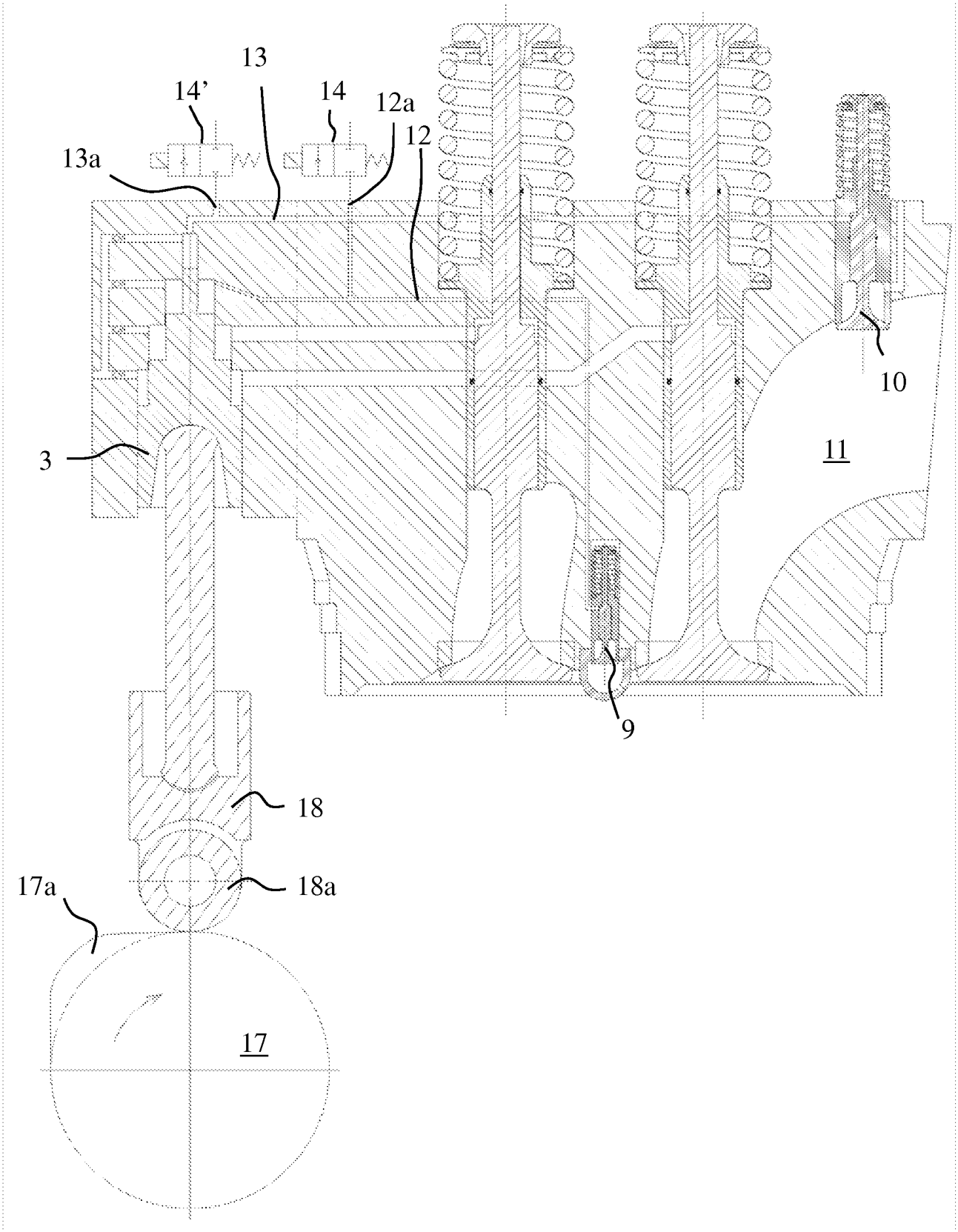

FIG. 2

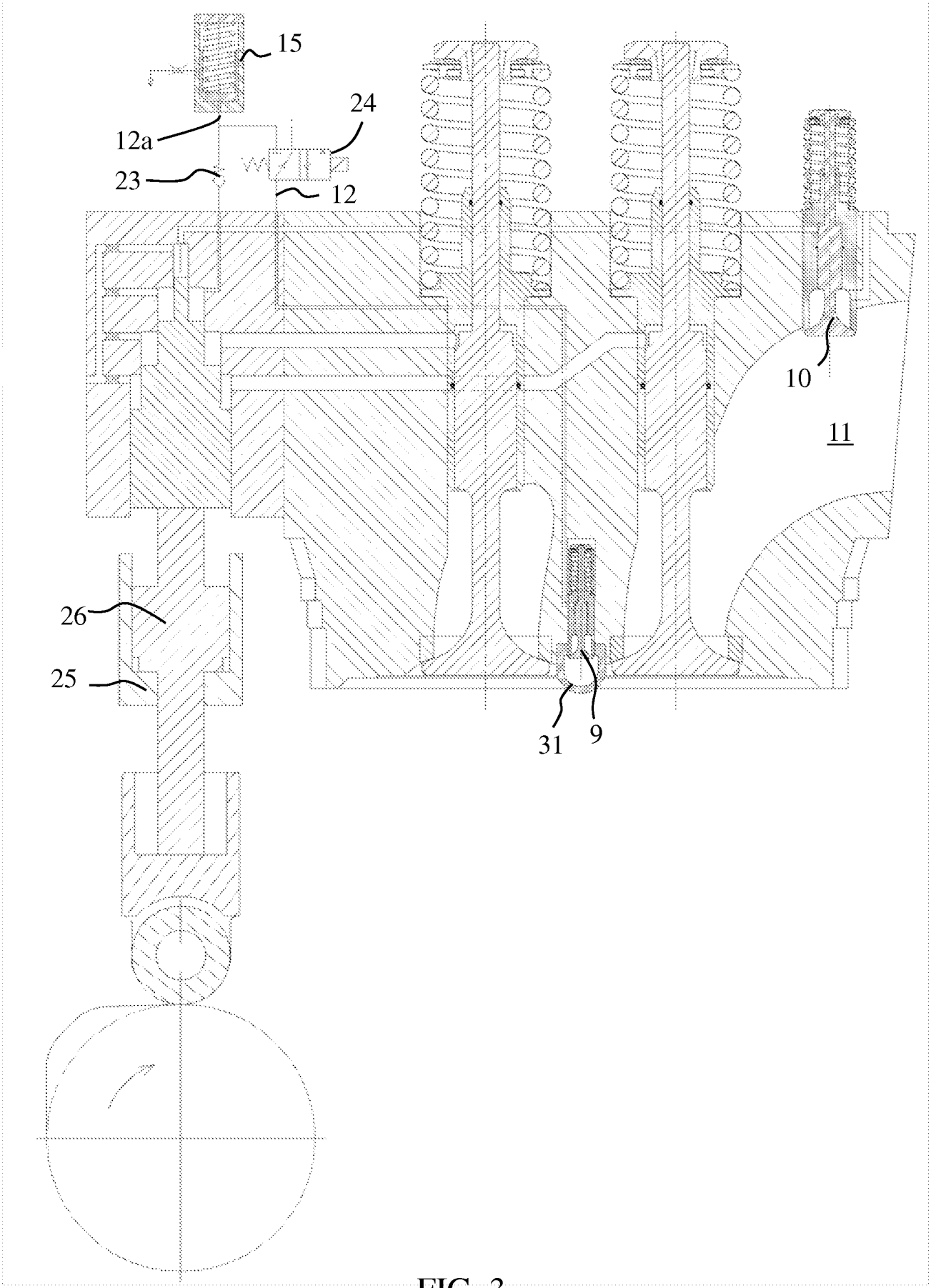

FIG. 3

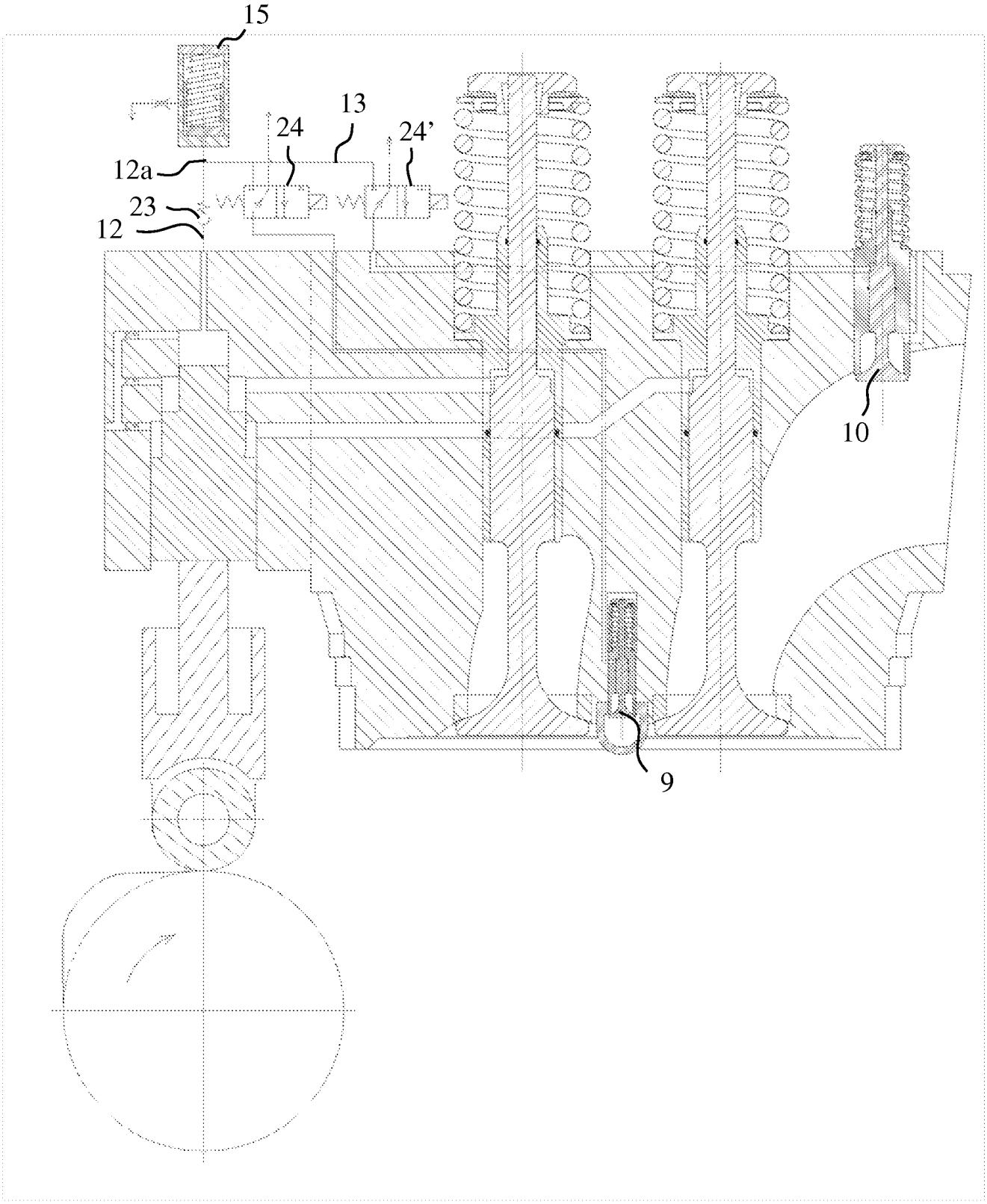

FIG. 4

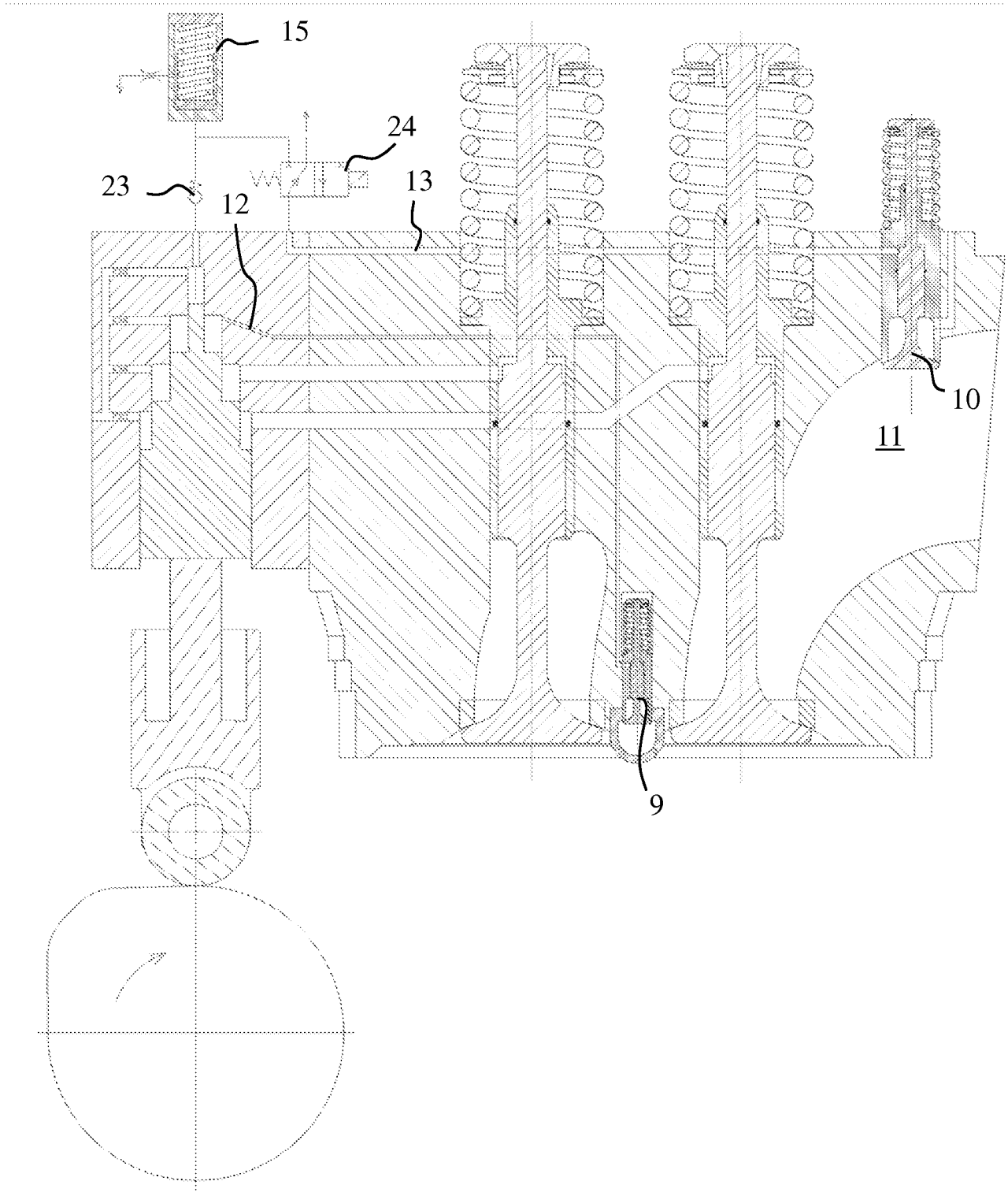

FIG. 5

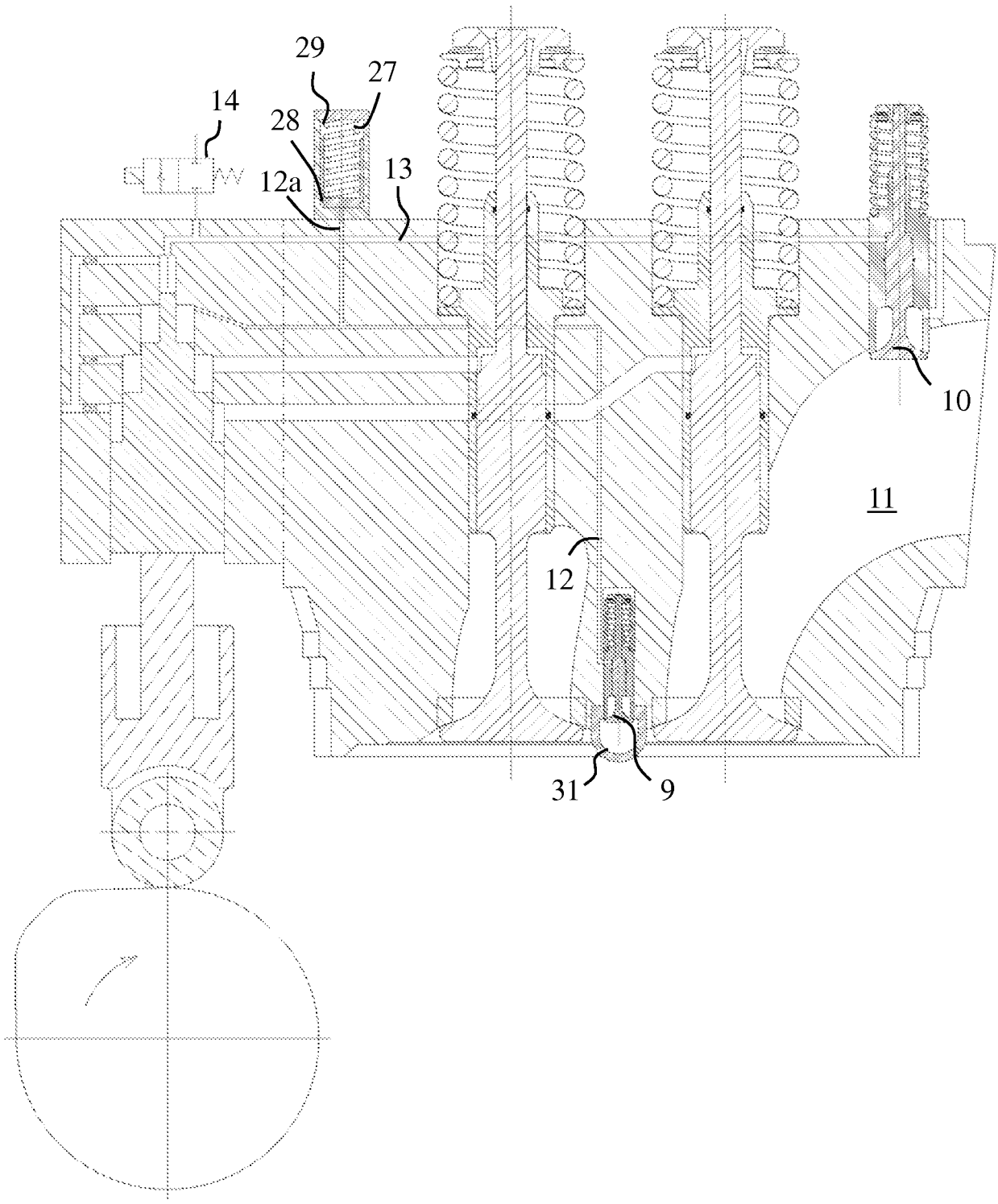

FIG. 6

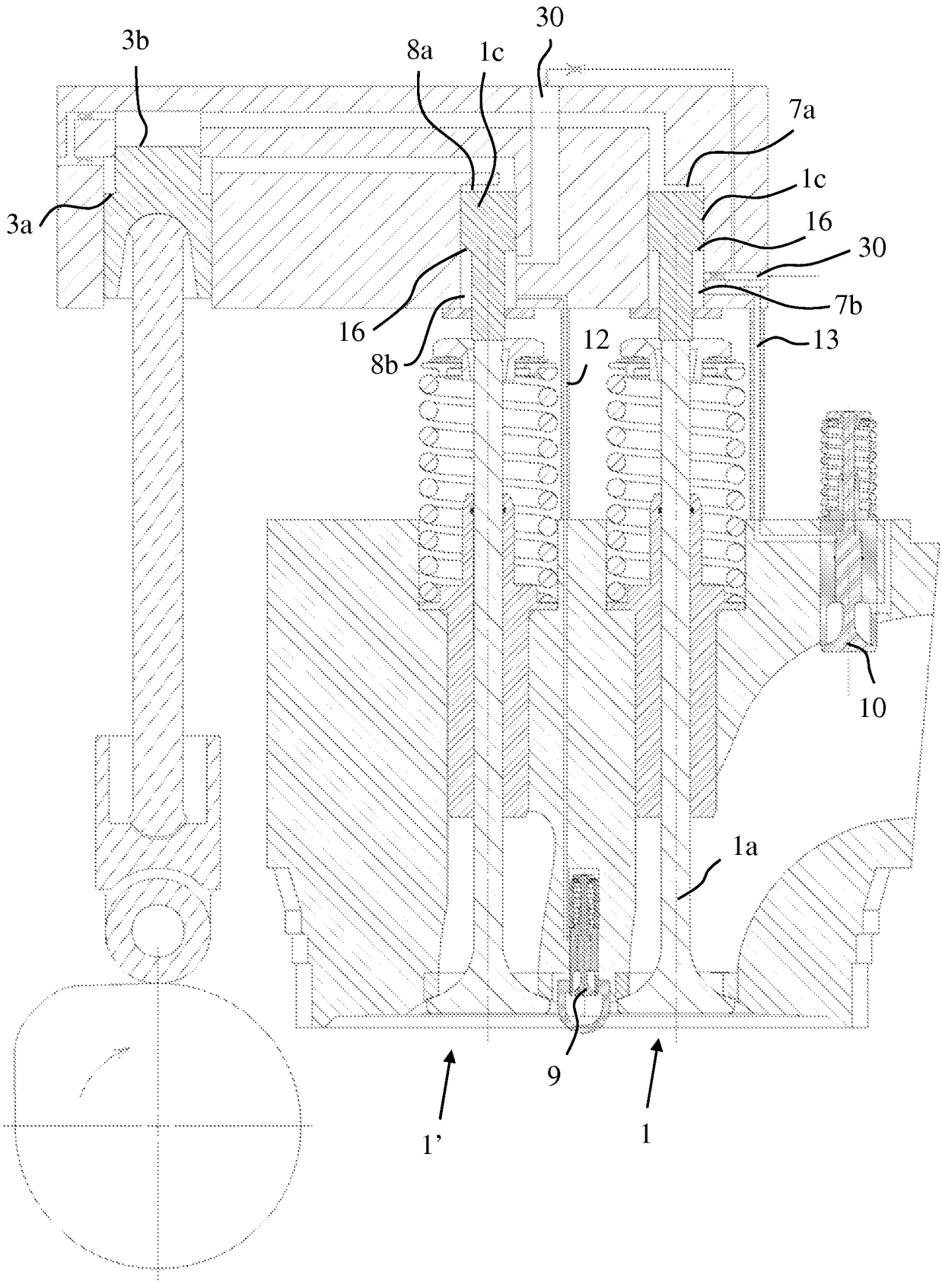

FIG. 7

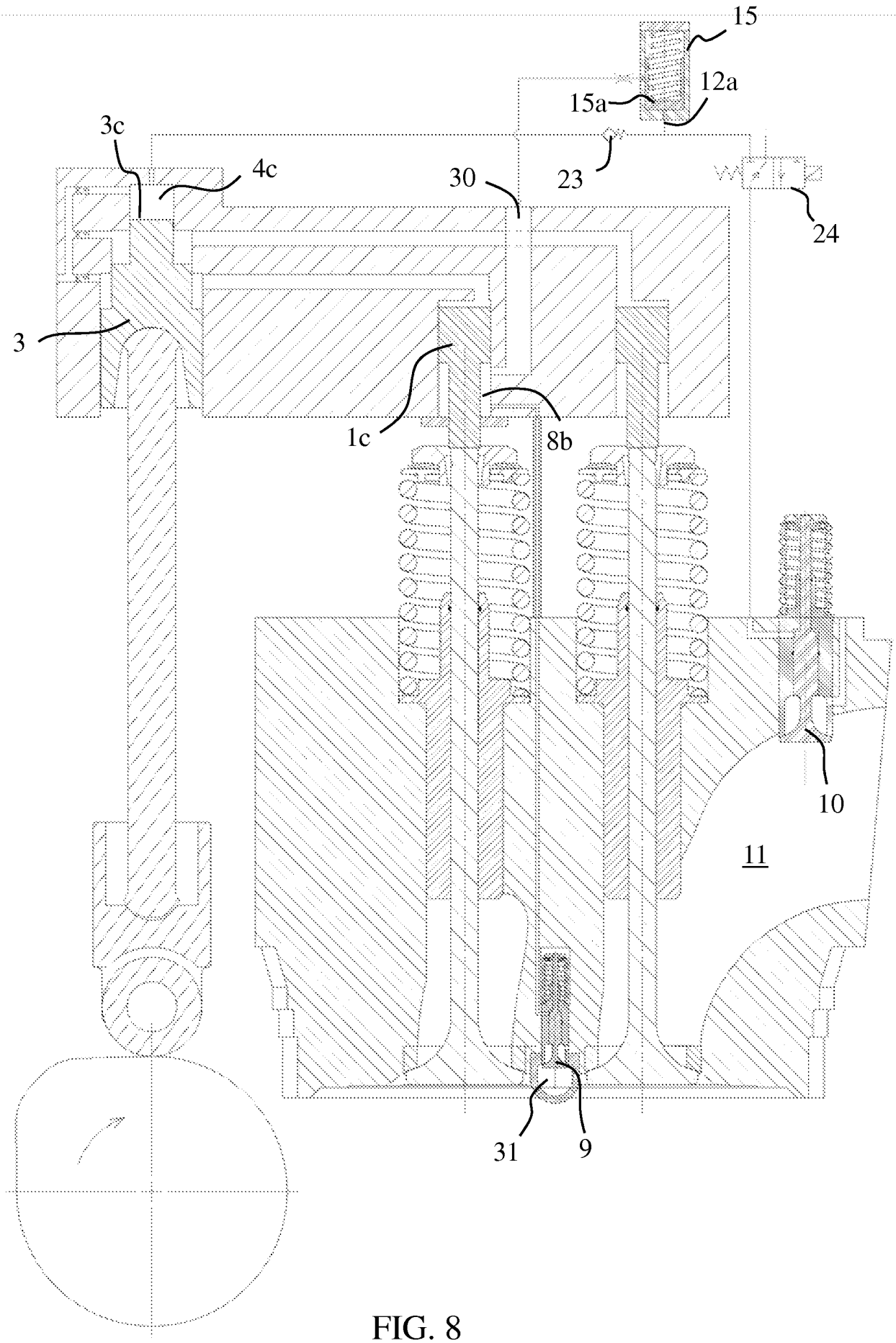

FIG. 8

INTERNATIONAL SEARCH REPORT

International application No
PCT/FI2013/050195

A. CLASSIFICATION OF SUBJECT MATTER
INV. F01L9/02
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)
F01L

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.
A	WO 99/25970 A1 (DIESEL ENGINE RETARDERS INC [US]) 27 May 1999 (1999-05-27) the whole document	1-10
A	DE 195 43 080 A1 (MAN B & W DIESEL AG [DE]) 22 May 1997 (1997-05-22) the whole document	1-10
A	EP 0 690 207 A1 (WAERTSILAE DIESEL INT [FI] WAERTSILAE NSD OY AB [FI]) 3 January 1996 (1996-01-03) the whole document	1-10
A	EP 0 515 307 A1 (NEW SULZER DIESEL AG [CH]) 25 November 1992 (1992-11-25) the whole document	1-10

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
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INTERNATIONAL SEARCH REPORT

International application No
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