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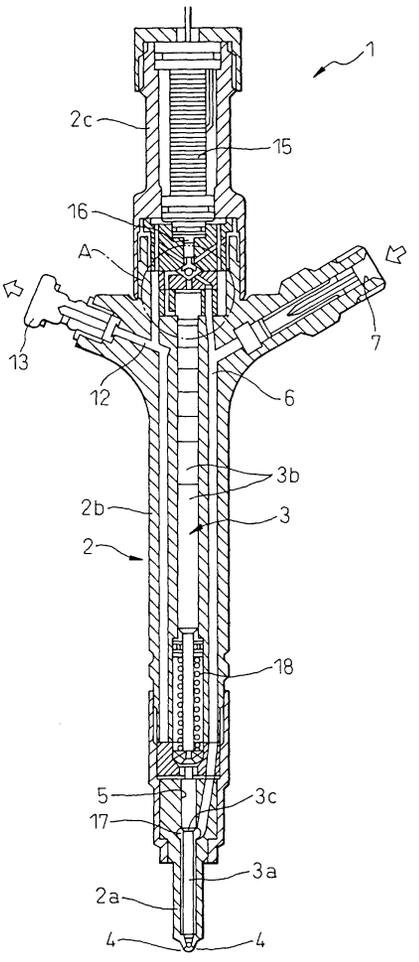
(54) Fuel injector

(57) A fuel injector (1) comprises a housing (2) with nozzles, a needle (3) movably accommodated in a needle accommodating chamber (5) formed in the housing, a fuel supply conduit (6) extending in the housing to the nozzles, a pressure control chamber (8) defined between the needle (3) and an inner wall of the needle accommodating chamber (5), a valve chamber (10) formed in the housing and connected to the pressure control chamber (8) via a communicating conduit, and a pressure control valve (14) accommodated in the valve chamber for controlling communication between the valve chamber and a relief conduit (12). When the pressure control valve (14) prevents communication between the valve chamber (10) and the relief conduit (12), fuel pressure in the pressure control chamber is increased and the needle is displaced in a first direction in which a volume of the pressure control chamber is increased and, when the pressure control valve connects the valve chamber and the relief conduit, a fuel pressure in the pressure control chamber drops and the needle is displaced in a second direction in which a volume of the pressure control chamber is reduced. The valve chamber is connected to the fuel supply conduit (6) via an inflowing conduit, so that fuel flows into the pressure control chamber from the fuel supply conduit through the valve chamber when the pressure control valve prevents communication between the valve chamber and the relief conduit.

Fig.1



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Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present invention relates to a fuel injector.

2. Description of the Related Art

[0002] PCT patent publication No. WO97/48900 discloses a fuel injector having a housing with a nozzle, a needle movably accommodated in a needle accommodating chamber formed in the housing, a fuel supply conduit extending in the housing to the nozzle, a pressure control chamber defined between the needle and an inner wall of the needle accommodating chamber, a valve chamber formed in the housing and connected to the pressure control chamber via a communicating conduit, the pressure control chamber and the valve chamber being filled with fuel, and a pressure control valve accommodated in the valve chamber for controlling a communication between the valve chamber and a relief conduit. In this fuel injector, the pressure control chamber is connected to the fuel supply conduit.

[0003] When the pressure control valve prevents communication between the valve chamber and the relief conduit, the fuel pressure in the pressure control chamber increases and the needle is displaced to close the nozzle. When the pressure control valve connects the valve chamber and the relief conduit, a fuel pressure in the pressure control chamber drops and the needle is displaced to open the nozzle.

[0004] Specifically, when the pressure control valve connects the valve chamber and the relief conduit, fuel in the pressure control chamber flows out to the relief conduit through the valve chamber, and thus the fuel pressure in the pressure control valve drops.

[0005] However, fuel at high pressure is always fed to the pressure control chamber via the inflowing conduit. This may prevent a rapid pressure drop in the pressure control chamber and, thus, may prevent a rapid displacement of the needle to open the nozzle and to conduct fuel injection.

SUMMARY OF THE INVENTION

[0006] An object of the invention is to provide a fuel injector which is capable of rapidly displacing the needle in a direction in which the needle opens the nozzle.

[0007] According to the present invention, there is provided a fuel injector comprising a housing with a nozzle, a needle movably accommodated in a needle accommodating chamber formed in the housing, a fuel supply conduit extending in the housing to the nozzle, a pressure control chamber defined between the needle and an inner wall of the needle accommodating chamber, a valve chamber formed in the housing and connected to the pressure control chamber via a communicating conduit, the pressure control chamber and the valve chamber being filled with fuel, and a pressure control valve accommodated in the valve chamber for controlling a communication between the valve chamber and a relief conduit, wherein, when the pressure control valve prevents a communication between the valve chamber and the relief conduit, a fuel pressure in the pressure control chamber increases and the needle is displaced in a first direction in which a volume of the pressure control chamber is increased and, when the pressure control valve connects the valve chamber and the relief conduit, a fuel pressure in the pressure control chamber drops and the needle is displaced in a second direction in which a volume of the pressure control chamber is reduced, characterized in that the valve chamber is connected to the fuel supply conduit via an inflowing conduit, so that fuel flows into the pressure control chamber from the fuel supply conduit through the valve chamber when the pressure control valve prevents communication between the valve chamber and the relief conduit.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] In the drawings:

Fig. 1 is an overall view of a fuel injector according to the present invention;
Fig. 2 is an enlarged view of a part A in Fig. 1;
Fig. 3 is an end view of a displacement control piston;
Fig. 4 is a time chart of an axial displacement of a needle;
Fig. 5 is an enlarged view similar to Fig. 2, for explaining an operation of a fuel injector shown in Fig. 1;
Fig. 6 is an enlarged view similar to Fig. 2, for explaining an operation of a fuel injector shown in Fig. 1;
Fig. 7 is an enlarged view similar to Fig. 2, illustrating another embodiment according to the present invention; and
Fig. 8 is an enlarged view similar to Fig. 2, illustrating another embodiment according to the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0009] Referring to Figs. 1 and 2, a fuel injector 1 comprises a housing 2 and a needle 3. The housing 2 includes a nozzle holder 2a with a pair of nozzles 4, a casing body 2b, a actuator casing 2c, and chamber defining members 2d, 2e, and 2f. The needle 3 includes a needle body 3a and a plurality of piston members 3b, and is accommodated in a needle accommodating chamber 5 formed in the housing 2, movably along its

longitudinal axis. The needle 3 is displaced to open or close the nozzles 4.

[0010] A fuel supply conduit 6 is formed in the housing 2 from a fuel inlet 7 formed in the housing 2 to the nozzles 4. The fuel inlet 7 is connected to a fuel source such as a common rail (not shown).

[0011] A pressure control chamber 8 is defined between the top end of the needle 3 and an inner wall of the needle accommodating chamber 5, in which a displacement control piston 9 is axially movably accommodated to divide the pressure control chamber 8 into first and second pressure control chambers 8a and 8b. The first pressure control chamber 8a is defined between the bottom end of the displacement control piston 9 and the top end of the needle 3, and the second pressure control chamber 8b is defined between the top end of the displacement control piston 9 and the inner wall of the needle accommodating chamber 5.

[0012] Referring to Figs. 2 and 3, the displacement control piston 9 includes an annular shoulder 9a, which limits a downward displacement of the piston 9 together with an annular shoulder 5a formed in the needle accommodating chamber 5. Note that an upward displacement of the piston 9 is limited by contact between the top end of the piston 9 and the top end wall of the needle accommodating chamber 5.

[0013] The displacement control piston 9 also includes, in its bottom surface, a central depression 9b and grooves 9c extending in a radial direction, which prevent the needle 3 from adhering to the piston 9.

[0014] Turning back to Figs. 1 and 2, a valve chamber 10 is also formed in the housing 2, which is connected to the pressure control chamber 8 via a communicating conduit. Specifically, the valve chamber 10 is connected to the first pressure control chamber 8a via a first communicating conduit 11a, and is connected to the second pressure control chamber 8b via a second communicating conduit 11b.

[0015] As described hereinafter, the pressure control chambers 8a and 8b and the valve chamber 14 are filled with fuel.

[0016] A relief conduit 12, formed in the housing 2, extends from the valve chamber 10 to a fuel outlet 13 formed in the housing 2. The fuel outlet 13 may be connected to a fuel tank (not shown).

[0017] A pressure control valve 14 is movably accommodated in the valve chamber 10 along its longitudinal axis. The pressure control valve 14 includes a ball-shaped member 14a and a rod-shaped member 14b, integral with each other.

[0018] The pressure control valve 14 is driven by an actuator 15 of a piezo-electronic type, accommodated in the housing 2. The actuator 15 controls an axial displacement of the pressure control valve 14 though a control of a fuel pressure in a fuel-filled chamber 16 between the actuator 15 and the pressure control valve 14. Specifically, when the actuator extends along its longitudinal axis, a fuel pressure in the chamber 16 increases, and thus the pressure control valve 14 displaces downwardly. When the actuator shrinks along its longitudinal axis, a fuel pressure in the chamber 16 drops, and thus the pressure control valve 14 displaces upwardly.

[0019] The fuel supply conduit 6 includes a fuel collecting chamber 17, formed therein, in which a pressure receiving surface 3c formed on the needle is arranged. Accordingly, the needle 3 is urged by the fuel pressure, in the fuel collecting chamber 17, in a direction in which the needle 3 opens the nozzles 4. The needle 3 is also urged by a compressed spring 18, arranged between the needle 3 and the inner wall of the needle accommodating chamber 5, in a direction in which the needle 3 closes the nozzles 4.

[0020] An inflowing conduit 19 branches off from the fuel supply conduit 6, and extends to the valve chamber 10. In this way, the valve chamber 10 communicates with the fuel supply conduit 6.

[0021] Note that, in the present embodiment, the first and second communicating conduits 11a and 11b, and the inflowing conduit 19 include chokes, formed therein, respectively.

[0022] Next, the operation of the fuel injector 1 according to the present embodiment will be explained by referring to Figs. 2, 4 to 6.

[0023] Fig. 4 shows a time chart of an axial displacement ND of the needle 3, according to the present embodiment. As shown in Fig. 4, when the fuel injection is to be started, first, the needle 3 is displaced or lifted upwardly by a displacement D1. Then, the needle 3 is further displaced upwardly by a displacement D2. After that, the needle 3 is displaced downwardly by a displacement (D1 + D2), in order to stop the fuel injection.

[0024] In other words, the needle 3 is first displaced from a zero-displaced position in which the nozzles 4 are closed, to an intermediate position which is between the zero-displaced position and a fully-displaced position. After that, the needle 3 is further displaced upwardly to the fully-displaced position, and then is returned to the zero-displaced position.

[0025] More specifically, when the fuel injection is to be stopped, the pressure control valve 14 is moved to a position where it prevents communication between the valve chamber 10 and the relief conduit 12, and connects the valve chamber 14 with the second pressure control chamber 8b, as shown in Fig. 2. In this condition, fuel supplied to the valve chamber 10 via the inflowing conduit 19 flows into the first and second pressure control chambers 8a and 8b via the respective communicating conduits 11a and 11b. This increases the fuel pressure in the second pressure control chamber 8b, and keeps the displacement control piston 9 in a lowermost position where its shoulder 9a contacts with the shoulder 5a of the needle accommodating chamber 5. Also, this increases the fuel pressure in the first pressure control chamber 8a, and keeps the needle 3 in the zero-displaced position.

[0026] In other words, a downward force acting on the needle 3 for closing the nozzles 4, which is provided by the fuel pressure in the pressure control chambers 8a and 8b and the biasing force of the spring 18, exceeds an upward force acting on the needle for opening the nozzles 4, which is provided by the fuel pressure in the fuel collecting chamber 17. Therefore, the nozzles 4 are kept closed.

[0027] Note that, in this condition, the top of the needle 3 and the bottom of the displacement control piston 9 are spaced apart from each other by a distance D1, and the top of the piston 9 and the top of the inner wall of the needle accommodating chamber 5 are spaced apart from each other by a distance D2.

[0028] When the fuel injection is to be started, the pressure control valve 14 is displaced downwardly to a position in which it communicates the valve chamber 10 with the relief conduit 12 and avoids a communication between the valve chamber 10 and the second pressure control chamber 8b, as shown in Fig. 5. In this condition, the fuel pressure in the second pressure control chamber 8b is kept high, and thus the displacement control piston 9 is kept at the lowermost position. Contrarily, fuel in the first pressure control chamber 8a flows out through the valve chamber 10 to the relief conduit 12, and thus the fuel pressure in the first pressure control chamber 8a drops.

[0029] As a result, the upward force acting on the needle 3 exceeds the downward force acting on the needle 3, and thus the needle 3 is displaced upwardly. In this way, the fuel injection is started.

[0030] The upward displacement of the needle 3 is limited by an abutment of the needle 3 with the displacement control piston 9, as shown in Fig. 5. In this way, the needle 3 is first displaced by the displacement D1.

[0031] After that, the pressure control valve 14 is displaced upwardly to a position in which it connects the valve chamber 10 with the relief conduit 12 and the second pressure control chamber 8b, respectively, as shown in Fig. 6. In this condition, fuel in the second pressure control chamber 8b flows out through the valve chamber 10 to the relief conduit 12, and thus the fuel pressure in the second pressure control chamber 8b also drops.

[0032] As a result, the downward force acting on the needle 3 exceeds the upward force acting on the needle 3, and thus the needle 3 together with the piston 9 is further displaced upwardly.

[0033] The upward displacement of the needle 3 and the displacement control piston 9 is limited by an abutment of the piston 9 with the inner wall of the needle accommodating chamber 5, as shown in Fig. 6. In this way, the needle 3 is further displaced by the displacement D2, or is fully displaced.

[0034] When the fuel injection is to be stopped, the pressure control valve 14 is turned back to the position shown in Fig. 2. This increases the fuel pressures in the first and second pressure control chambers 8a and 8b. As a result, the downward force acting on the needle 3 exceeds the upward force acting on the needle 3, and thus the needle 3 and the displacement control piston 9 are displaced downwardly, until the needle 3 closes the nozzles 4 and the shoulder 9a of the piston 9 abuts with the shoulder 5a of the needle accommodating chamber 5.

[0035] In this way, three different conditions are obtained by a single pressure control valve 14.

[0036] In the present embodiment, the inflowing conduit 19 opens not to the first and second pressure control chambers 8a and 8b, but to the valve chamber 10. This promotes the pressure drop in the first and second pressure control chambers 8a and 8b, which promotes the rapid upward displacement of the needle 3.

[0037] As explained above, when the pressure control valve 14 connects the valve chamber 10 with the relief conduit 12 as shown in Figs. 5 and 6, fuel in the first pressure control chamber 8a flows out to the valve chamber 10 through the first communicating conduit 11a, and then flows out to the relief conduit 12 through an annular conduit formed around the pressure control valve 14.

[0038] In this condition, an upward displacement rate of the needle 3 depends on a flow rate of fuel through the first communicating conduit 11a, rather than that through the annular conduit. Specifically, the flow resistance of the first communicating conduit 11a is set higher than that of the annular conduit.

[0039] The fuel flow rate through the annular conduit depends on a magnitude of a clearance formed between the pressure control valve 9 and the valve chamber 10, which depends, in turn, on the axial displacement of the valve 9. Therefore, if the upward displacement rate of the needle 3 depends on a fuel flow rate through the annular conduit, a critical control of the axial displacement of the valve 9 is required for maintaining the displacement rate of the needle 3 constant. The present embodiment avoids such a critical control.

[0040] As the same reasons, the flow resistance of the second communicating conduit 11b is set higher than that of the annular conduit.

[0041] On the other hand, the flow resistance of the inflowing conduit 19 is set relatively low. This quickly increases the fuel pressure in the valve chamber 10, and thus the pressures in the first and second pressure control chambers 8a and 8b, when the pressure control valve 14 prevents communication between the valve chamber 14 and the relief conduit 12. This ensures a quick downward displacement of the needle 3.

[0042] The displacement of the needle 3 is controlled through control of the displacement control piston 9, which is obtained through control of the fuel pressure in the first and second pressure control chambers 8a and 8b. This avoids a control of a fuel pressure in the fuel supply conduit 6 for a control of a displacement of the needle 3.

[0043] As explained above, the pressure control valve

14 is connected to the actuator 15 of a piezo-electric type, indirectly, i.e., via the fuel-filled chamber 16 (see Fig. 1). In general, an axial length of a piezo-electric element may vary with its temperature change, and thus a direct connection of the valve 14 to the actuator 15 may deteriorate control of the axial displacement of the valve 14. The present embodiment avoids such a problem.

[0044] Fig. 7 shows another embodiment of the present embodiment. In Fig. 7, the same reference numerals are used for the same or similar constituents as in Fig. 1.

[0045] An additional inflowing conduit 19 connecting the second pressure control chamber 8b to the inflowing conduit 19 or the fuel supply conduit 6 is added to the embodiment shown in Fig. 1. Specifically, the chamber defining member 2e shown in Fig. 1 is replaced by two chamber defining members 2e' and 2e", in which the additional inflowing conduit 20b having a choke is formed.

[0046] Fuel in the fuel supply conduit 6 flows into the second pressure control chamber 8b via the additional inflowing conduit 20b. This promotes a quick downward displacement of the needle 3. In particular, when the second pressure control chamber 8b communicates with the valve chamber 10, fuel flows both from the valve chamber 10 and the fuel supply conduit 6.

[0047] Flow resistance of the additional inflowing conduit 20b is set higher than that of the second communicating conduit 11b. This promotes a quick pressure drop in the second pressure control chamber 8b when the pressure control valve 14 connects the second chamber 8b with the relief conduit 12 (see Fig. 6), which thus promotes a quick upward displacement of the needle 3.

[0048] Fig. 8 shows another embodiment of the present embodiment. In Fig. 8, the same reference numerals are used for the same or similar constituents as in Figs. 1 and 7.

[0049] A further additional inflowing conduit 20a connecting the second pressure control chamber 8b to the inflowing conduit 19 or the fuel supply conduit 6 is added to the embodiment shown in Fig. 7. Specifically, the conduit 20a having a choke is formed in the piston members 3b of the needle 3 and the casing body 2b of the housing 2. Note that the conduit 20a is referred to a first additional inflowing conduit, and the conduit 20b is referred to a second additional inflowing conduit, hereinafter.

[0050] Fuel in the fuel supply conduit 6 also flows into the first pressure control chamber 8a via the first additional inflowing conduit 20a. This also promotes a quick downward displacement of the needle 3. In particular, when the first pressure control chamber 8a communicates with the valve chamber 10, fuel flows from both the valve chamber 10 and the fuel supply conduit 6.

[0051] Flow resistance of the first additional inflowing conduit 20a is set higher than that of the first communicating conduit 11a. This promotes a quick pressure drop in the first pressure control chamber 8a when the pressure control valve 14 communicates the first chamber 8a with the relief conduit 12 (see Figs. 5 and 6), which thus promotes a quick upward displacement of the needle 3.

[0052] In some engines, a fuel injection pressure and, thus, a fuel pressure in the fuel supply conduit 6 are set relatively low, in order to suppress a combustion noise generated during an idling engine operation. This, however, reduces the downward force acting on the needle 3 by the fuel pressure in the first pressure control chamber 8a when the nozzles 4 are to be closed, which increases a ratio of the downward force by the spring 18 (see Fig. 1) to a total downward force. In this situation, a rapid pressure drop in the first pressure control chamber 8a is required for a quick upward displacement of the needle 3.

[0053] Therefore, relatively high flow resistance of the first additional inflowing conduit 20a is preferable when the fuel injection pressure is relatively low. An omission of the first additional inflowing conduit 20a, as in the embodiments shown in Fig. 1 and 7 is more preferable in this regard.

[0054] The embodiments described above include the displacement control piston 9 arranged in the pressure control chamber 8. Alternatively, the piston 9 may be omitted to provide a single pressure control chamber, a single communicating conduit, and a single additional inflowing conduit.

[0055] According to the present invention, it is possible to provide a fuel injector which is capable of rapidly displacing the needle in a direction in which the needle opens the nozzle.

[0056] A fuel injector comprises a housing with nozzles, a needle movably accommodated in a needle accommodating chamber formed in the housing, a fuel supply conduit extending in the housing to the nozzles, a pressure control chamber defined between the needle and an inner wall of the needle accommodating chamber, a valve chamber formed in the housing and connected to the pressure control chamber via a communicating conduit, and a pressure control valve accommodated in the valve chamber for controlling communication between the valve chamber and a relief conduit. When the pressure control valve prevents communication between the valve chamber and the relief conduit, fuel pressure in the pressure control chamber is increased and the needle id displaced in a first direction in which a volume of the pressure control chamber is increased and, when the pressure control valve connects the valve chamber and the relief conduit, a fuel pressure in the pressure control chamber drops and the needle is displaced in a second direction in which a volume of the pressure control chamber is reduced. The valve chamber is connected to the fuel supply conduit via an inflowing conduit, so that fuel flows into the pressure control chamber from the fuel supply conduit through the valve chamber when the pressure control valve prevents communication between the valve chamber and the relief conduit.

Claims

1. A fuel injector comprising a housing with a nozzle, a needle movably accommodated in a needle accommodating chamber formed in the housing, a fuel supply conduit extending in the housing to the nozzle, a pressure control chamber defined between the needle and an inner wall of the needle accommodating chamber, a valve chamber formed in the housing and connected to the pressure control chamber via a communicating conduit, the pressure control chamber and the valve chamber being filled with fuel, and a pressure control valve accommodated in the valve chamber for controlling a communication between the valve chamber and a relief conduit, wherein, when the pressure control valve prevents a communication between the valve chamber and the relief conduit, a fuel pressure in the pressure control chamber increases and the needle is displaced in a first direction in which a volume of the pressure control chamber is increased, and, when the pressure control valve connects the valve chamber and the relief conduit, a fuel pressure in the pressure control chamber drops and the needle is displaced in a second direction in which a volume of the pressure control chamber is reduced, **characterized in that** the valve chamber is connected to the fuel supply conduit via an inflowing conduit, so that fuel flows into the pressure control chamber from the fuel supply conduit through the valve chamber when the pressure control valve prevents communication between the valve chamber and the relief conduit.

2. A fuel injector according to claim 1, **characterized in that** fuel flows into the pressure control chamber only from the valve chamber via the communicating conduit.

3. A fuel injector according to claim 1, **characterized in that** the pressure control chamber is connected to the fuel supply conduit via an additional conduit, so that fuel flows into the pressure control chamber from the valve chamber via the communicating conduit and from the fuel supply conduit via the additional conduit.

4. A fuel injector according to claim 1, **characterized in that** a displacement control piston is movably accommodated in the pressure control chamber for controlling a displacement of the needle, the displacement control piston dividing the pressure control chamber into first and second pressure control chambers, the first pressure control chamber being defined between the displacement control piston and the needle, and the second pressure control chamber being defined between the displacement control piston and the inner wall of the needle accommodating chamber, and that the communicating conduit includes first and second communicating conduits, the first communicating conduit extending between the first pressure control chamber and the valve chamber, and the second communicating conduit extending between the second pressure control chamber and the valve chamber.

5. A fuel injector according to claim 4, **characterized in that** fuel flows into the first and second pressure control chambers only from the valve chamber via the respective first and second communicating conduits.

6. A fuel injector according to claim 4, **characterized in that** the first pressure control chamber is connected to the fuel supply conduit via a first additional conduit, so that fuel flows into the first pressure control chamber from the valve chamber via the first communicating conduit and from the fuel supply conduit via the first additional conduit.

7. A fuel injector according to claim 4, **characterized in that** the second pressure control chamber is connected to the fuel supply conduit via a second additional conduit, so that fuel flows into the second pressure control chamber from the valve chamber via the second communicating conduit and from the fuel supply conduit via the second additional conduit.

8. A fuel injector according to claim 4, **characterized in that** the pressure control valve also controls communication between the valve chamber and the second pressure control chamber, wherein, when the pressure control valve prevents communication between the valve chamber and the relief conduit and connects the valve chamber and the second pressure control chamber, fuel pressures in the first and second pressure control chambers increase and the needle and the displacement control piston displace in the first direction, when the pressure control valve communicates the valve chamber and the relief conduit and prevents communication between the valve chamber and the second pressure control chamber, a fuel pressure in the first pressure control chamber drops and the needle is displaced by a first displacement in the second direction while the displacement control piston keeps its position and, when the pressure control valve connects the valve chamber and the relief conduit and connects the valve chamber and the second pressure control chamber, fuel pressures in the first and second pressure control chambers drop and the needle and the displacement control piston are displaced by a second displacement in the second direction, the second displacement being larger than the first displacement.

9. A fuel injector according to claim 1, **characterized in that** a fuel collecting chamber is formed in the fuel supply conduit, and **that** a pressure receiving surface formed on the needle is arranged in the fuel collecting chamber to urge the needle in the second direction.

10. A fuel injector according to claim 1, **characterized in that** the needle is displaced in the first direction when the fuel injection is to be stopped, and is displaced in the second direction when the fuel injection is to be started.

Fig.1

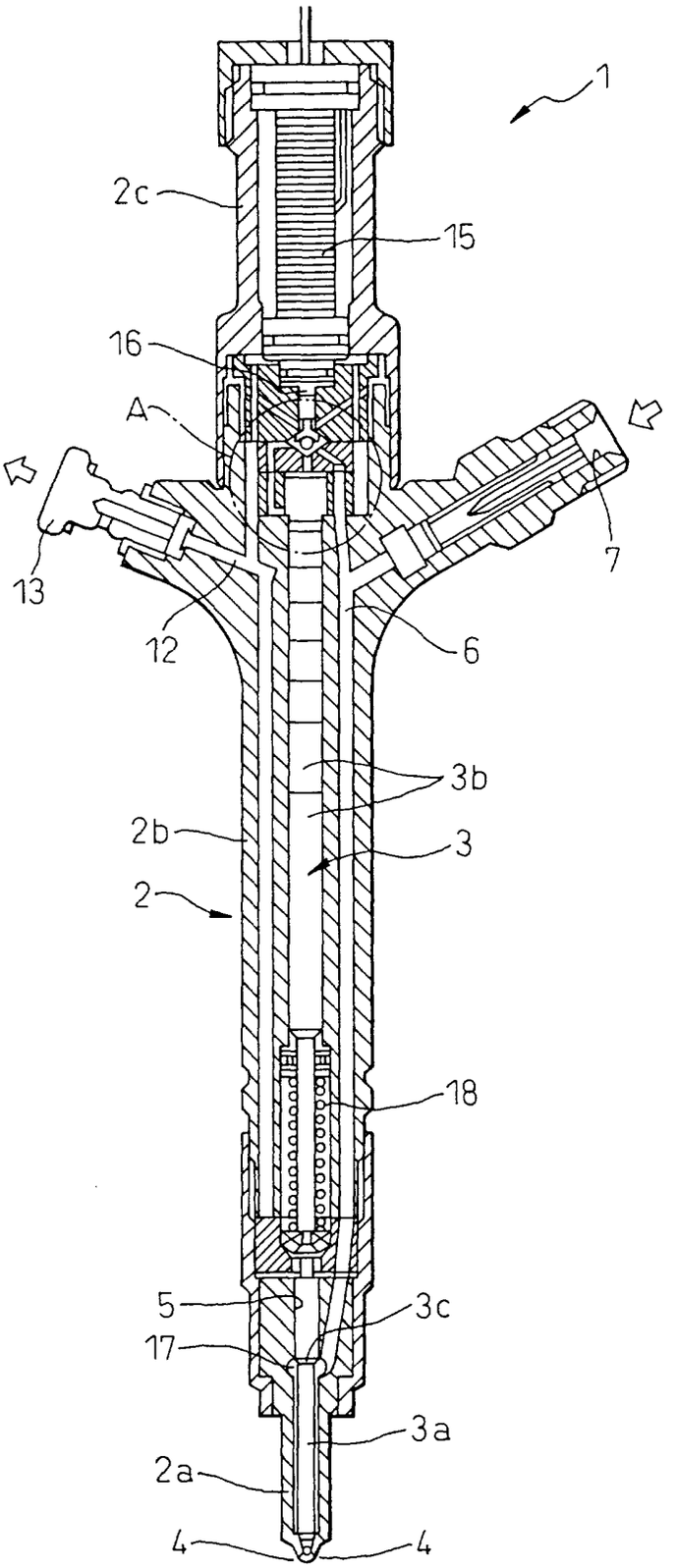
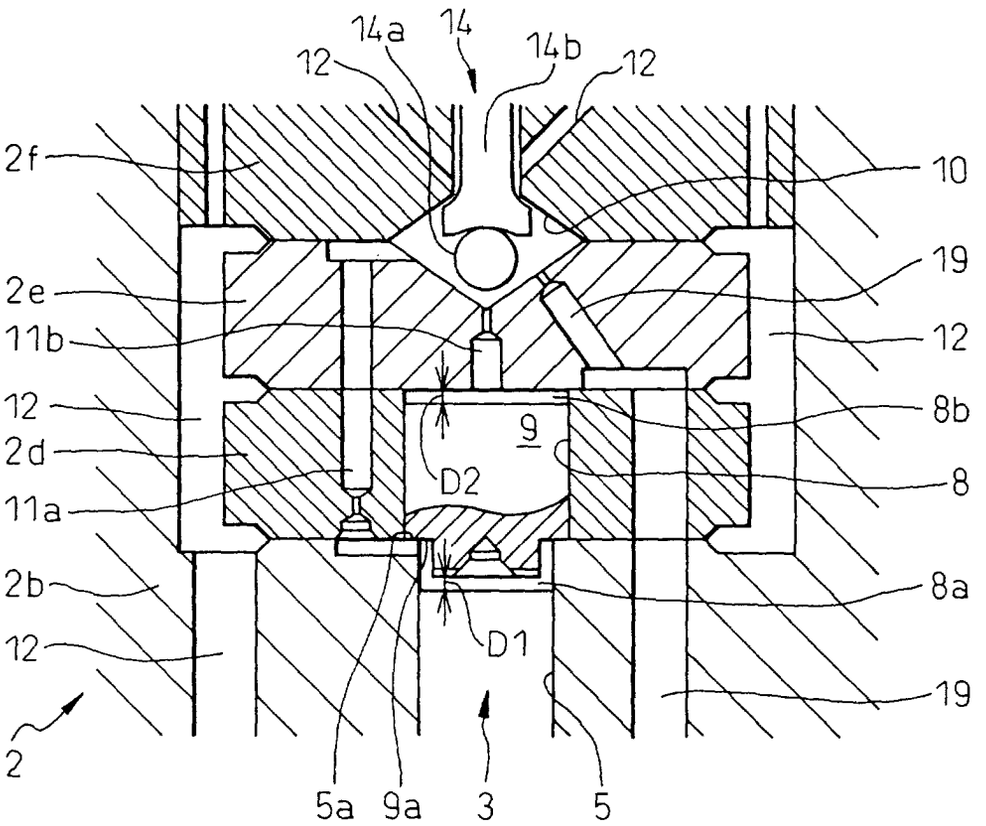


Fig.2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14b
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12
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12
12
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9
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8a
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D1
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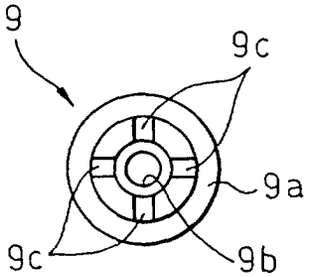
2
5a
9a
3
5

Fig.3


9
9c
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9c
9b

Fig.4

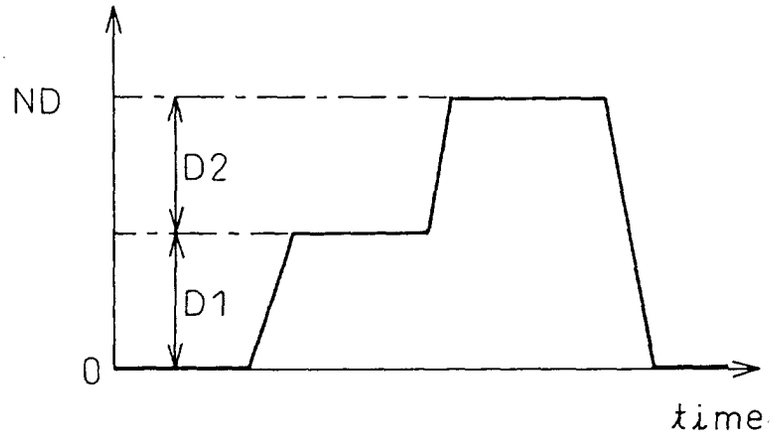

Fig.5

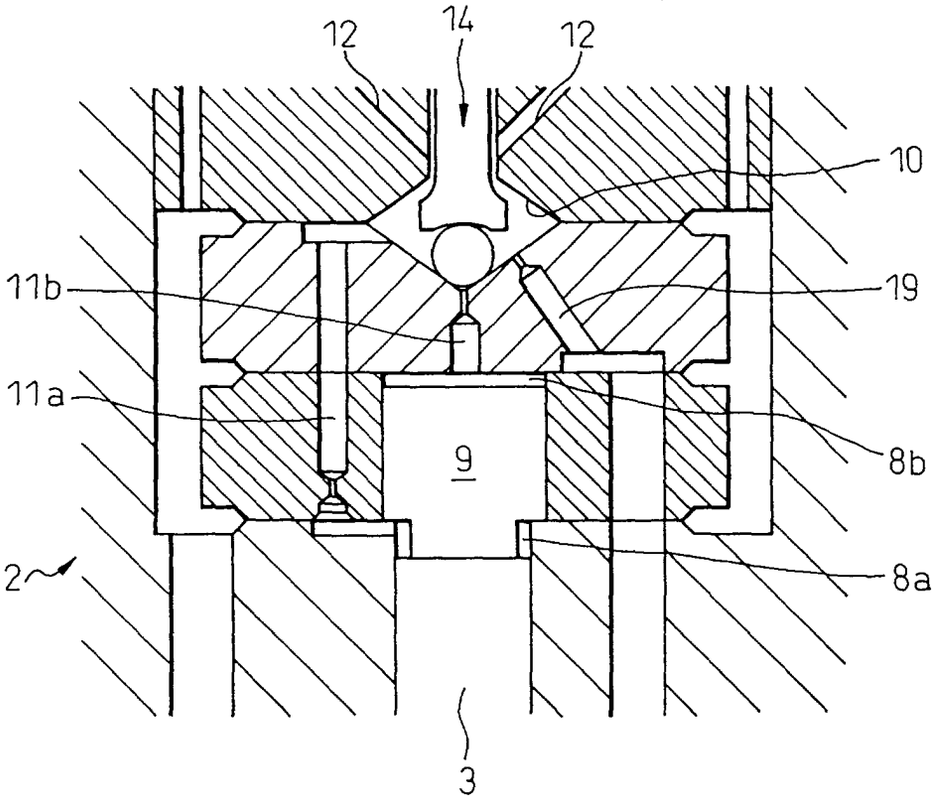

Fig. 6

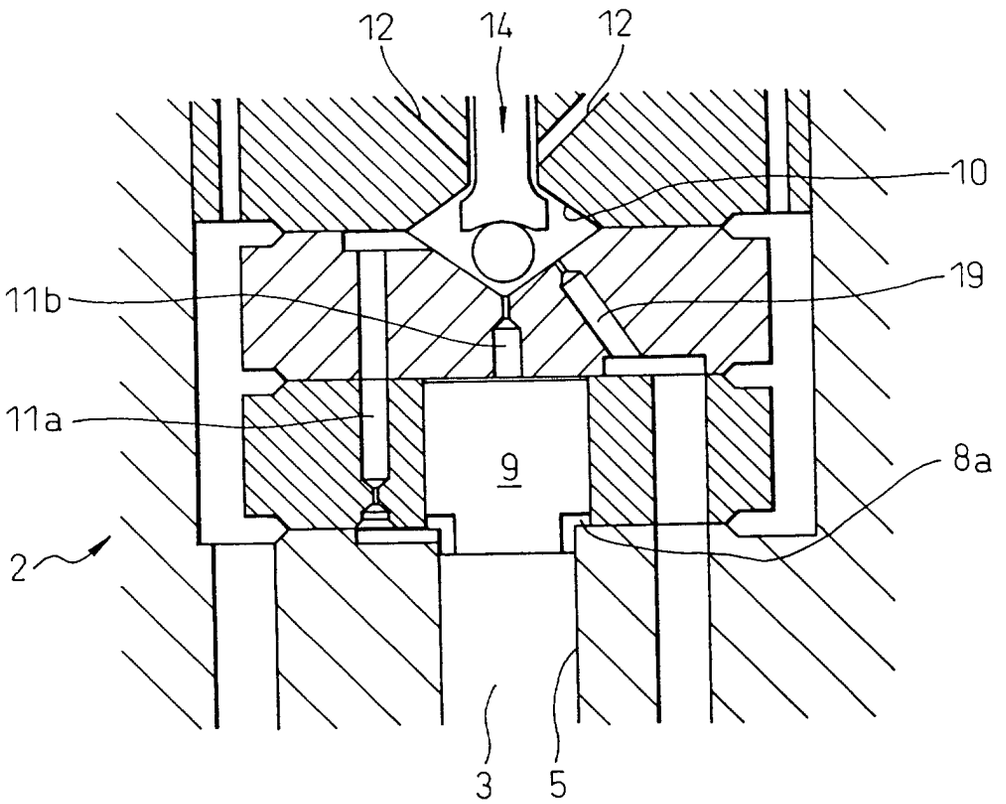

Fig. 7

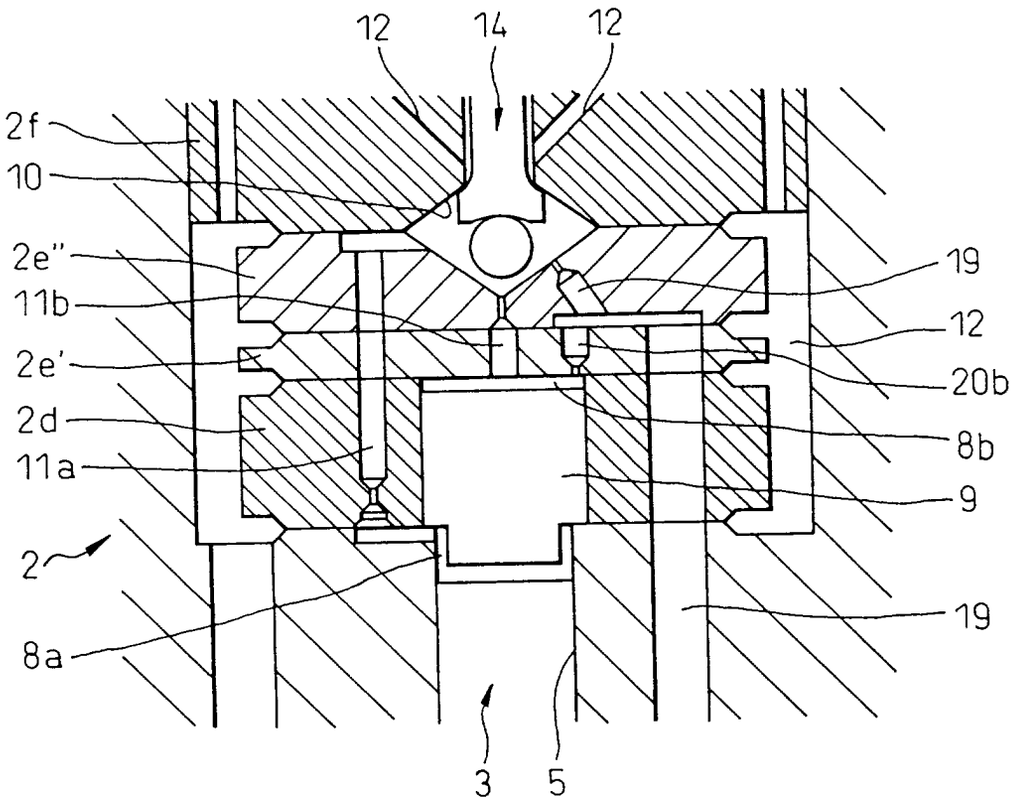

Fig.8