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(54) **Fuel injector**

(57) A fuel injector comprising a housing with a nozzle, a needle movably accommodated in a needle accommodating chamber formed in the housing, for opening or closing the nozzle, a pressure control chamber defined between the needle and an inner wall of the needle accommodating chamber and filled with a fuel, a displacement of the needle depending on the fuel pressure in the pressure control chamber, a pressure control valve movably provided in the housing for controlling the fuel pressure in the pressure control chamber; and an actuator for controlling a displacement of the pressure control valve. The needle is displaced to a position in which it closes the nozzle when the pressure control valve is displaced to the zero-displaced position, is displaced to a position in which it partly opens the nozzle when the pressure control valve is displaced to an intermediate position, and is displaced to a position in which it fully opens the nozzle when the pressure control valve is displaced to a fully-displaced position.

Fig.1

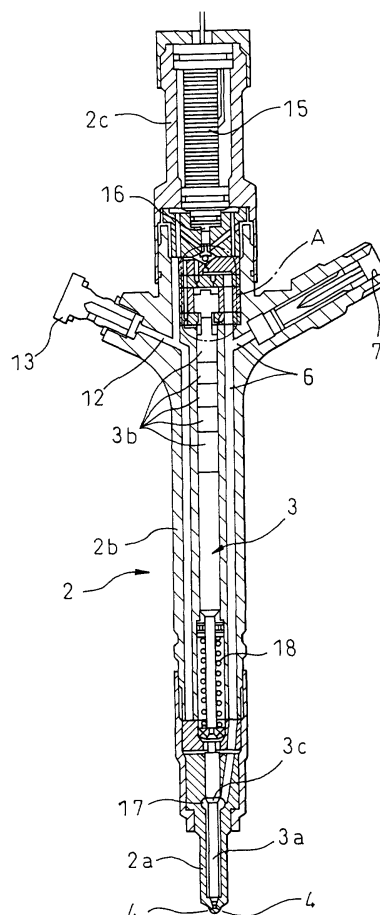
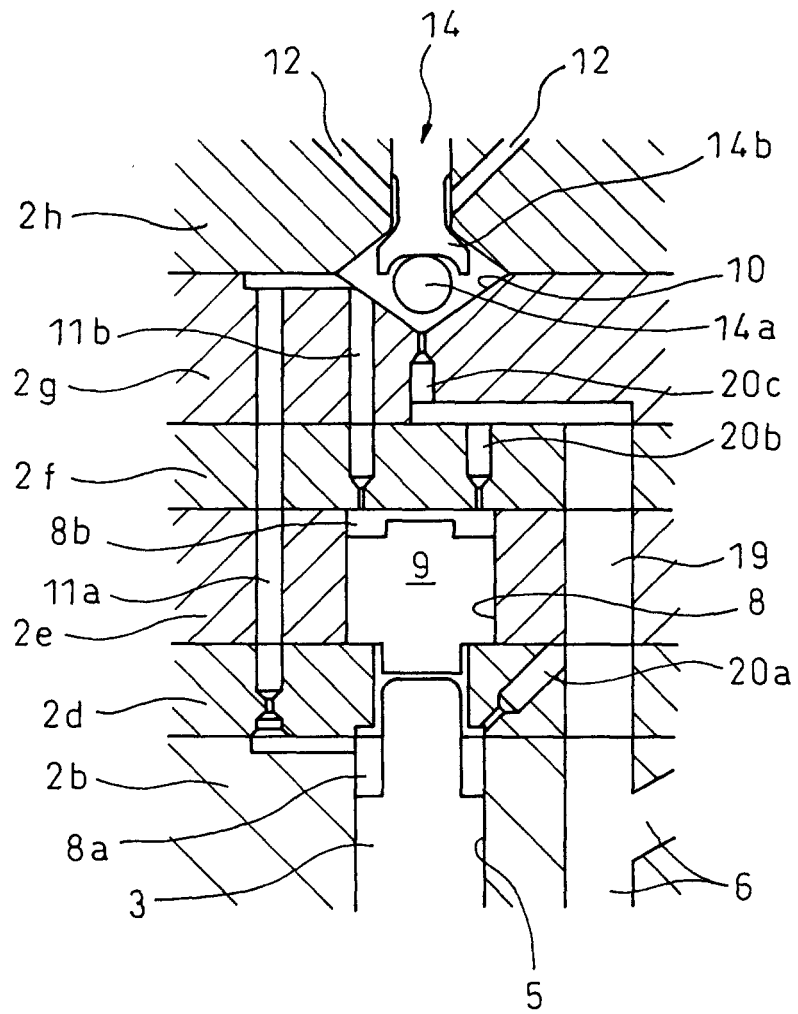


Fig. 2



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] Japanese Unexamined Patent Publication No. 8-334072 discloses a fuel injector having a housing with a nozzle, a needle movably accommodated in a needle accommodating chamber formed in the housing, and a control valve for controlling a displacement of the needle. In this fuel injector, the control valve is displaced by the pressure applied to the fuel injector, and is displaced to a zero-displaced position when the fuel pressure is low, to a fully-displaced position when the fuel pressure is high, and to an intermediate position between the zero displaced and the fully-displaced positions when the fuel pressure is medium.

[0003] The needle can displace fully when the control valve is displaced to the zero-displaced position or a fully-displaced position, and can displace partly when the control valve is displaced to the intermediate position.

[0004] However, during the displacement of the control valve from the zero-displaced position to the fully-displaced position, the control valve must pass the intermediate position in which the displacement of the needle is limited. This may prevent a rapid displacement of the needle to open the nozzle fully.

SUMMARY OF THE INVENTION

[0005] An object of the invention is to provide a fuel injector which is capable of rapidly displacing the needle.

[0006] 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, for opening or closing the nozzle; a pressure control chamber defined between the needle and an inner wall of the needle accommodating chamber and filled with a fuel, a displacement of the needle depending on the fuel pressure in the pressure control chamber; a pressure control valve movably provided in the housing for controlling the fuel pressure in the pressure control chamber; and an actuator for controlling a displacement of the pressure control valve; wherein the needle is displaced by a first displacement when the pressure control valve is displaced to the zero-displaced position, wherein the needle is displaced by a second displacement when the pressure control valve is displaced to the fully-displaced position, wherein the needle is displaced by a third displacement when the pressure control valve is displaced to an intermediate position between the zero-

displaced position and the fully-displaced position, and wherein the third displacement is between the first and second displacements.

5 BRIEF DESCRIPTION OF THE DRAWINGS

[0007] 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 a partly enlarged view of the fuel injector;

Fig. 4 is an enlarged view, similar to Fig. 2, for explaining an operation of a fuel injector shown in Fig. 1;

Fig. 5 is an enlarged view, similar to Fig. 2, for explaining an operation of a fuel injector shown in Fig. 1;

Figs. 6 to 11 show various embodiments of the fuel injection; and

Fig. 12 is an enlarged view, similar to Fig. 2, illustrating another embodiment according to the present invention.

25 DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0008] Referring to Figs. 1 to 3, 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, an actuator casing 2c, and chamber defining members 2d, 2e, 2f, 2g, and 2h. 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.

[0009] 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 high pressure fuel source such as a common rail (not shown) with a constant fuel pressure.

[0010] 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 pressure control chamber 8 a displacement control piston 9 is axially and 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.

[0011] 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.

[0012] A valve chamber 10 is also formed in the housing 2, which is connected to the pressure control chamber 8 via a discharging conduit. Specifically, the valve chamber 10 is connected to the first pressure control chamber 8a via a first discharging conduit 11a, and is connected to the second pressure control chamber 8b via a second discharging conduit 11b.

[0013] As described hereinafter, the pressure control chambers 8a and 8b and the valve chamber 10 are filled with fuel.

[0014] Relief conduits 12, formed in the housing 2, extend 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).

[0015] 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.

[0016] 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 through 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.

[0017] 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.

[0018] A high fuel pressure conduit 19 branches off from the fuel supply conduit 6, and is connected to the first and the second pressure control chambers 8a and 8b via first and second inflowing conduit 20a and 20b, respectively. The high fuel pressure conduit 19 is also connected to the valve chamber 10 via a third inflowing conduit 20c.

[0019] Note that, in the present embodiment, the first and second discharging conduits 11a and 11b, and the first, second, and third inflowing conduits 20a, 20b, 20c include chokes formed therein.

[0020] The flow resistance of the second inflowing conduit 20b is set smaller than that of the first inflowing conduit 20a, and the flow resistance of the second discharging conduit 11b is set larger than that of the first discharging conduit 11a. Further, a hydro erosive grinding is applied only in a direction from the valve chamber 10 to the pressure control chamber 8b, so that a discharge coefficient of the second discharging conduit 11b in a direction from the second pressure control chamber 8b to the valve chamber 10 is set smaller than that in a direction from the valve chamber 10 to the pressure control chamber 8b. Therefore, the pressure in the second pressure control chamber 8b is easily increased but difficult to reduce, with respect to the pressure in the first pressure control chamber 8a.

[0021] Fig. 2 shows the case where the pressure control valve 14 is in a zero-displaced position. In this position, the pressure control valve 14 prevents communication between the valve chamber 10 and the relief conduits 12, and connects the valve chamber 10 with the high fuel pressure conduit 19. In this condition, fuel in the high fuel pressure conduit 19 flows into the first pressure control chamber 8a, via the first inflowing conduit 20a, and via the third inflowing conduit 20c, the valve chamber 10, and the first discharging conduit 11a. Also, fuel flows into the second pressure control chamber 8b via the second inflowing conduit 20b, and via the third inflowing conduit 20c, the valve chamber 10, and the second discharging conduit 11b.

[0022] 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. Therefore, 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. Accordingly, the needle 3 closes nozzles 4.

[0023] 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, as shown in Fig. 3.

[0024] Fig. 4 shows the case where the pressure control valve 14 is in an intermediate position or is displaced by a small displacement SD from the zero-displacement position. In this position, the pressure control valve 14 partly connects the valve chamber 10 with the relief conduits 12, and connects the valve chamber 10 with the high fuel pressure conduit 19. In this condition, fuel flows into the first pressure control chamber 8a via the first inflowing conduit 20a. However, fuel in the first pressure

control chamber 8a flows out therefrom via the first discharging conduit 11a and the valve chamber 10 to the relief conduits 12. Therefore, the pressure in the first pressure control chamber 8a drops. 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.

[0025] On the other hand, at this time, fuel flows into the second pressure control chamber 8b via the second inflowing conduit 20b and the second discharging conduit 11b. Note that, in the present embodiment, magnitudes of the opening formed between the valve chamber 10 and the relief conduits 12 and the flow resistances of the conduits 11a, 11b, 20a, and 20b are set so that the fuel flows from the valve chamber 10 to the second pressure control chamber 8b even if the valve chamber 10 is connected to the relief conduits 12. Therefore, the pressure in the second pressure control chamber 8b is kept high, and thus the displacement control piston 9 is kept at the lowermost position.

[0026] 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 displaced by the displacement D1 or partly opens the nozzles 4, by the small displacement of the pressure control valve 14.

[0027] Fig. 5 shows the case where the pressure control valve 14 is in a fully-displaced position or is displaced by a full displacement FD from the zero-displacement position. In this position, the pressure control valve 14 connects the valve chamber 10 with the relief conduits 12, and prevents communication between the valve chamber 10 and the high fuel pressure conduit 19. In this condition, the pressure in the first pressure control chamber 8a is kept low because fuel in the first pressure control chamber 8a flows out therefrom via the first discharging conduit 11a and the valve chamber 10 to the relief conduits 12.

[0028] At this time, fuel in the second pressure control chamber 8b also flows out therefrom via the second discharging conduit 11b and the valve chamber 10 to the relief conduits 12. Therefore, the fuel pressure in the second pressure control chamber 8b also drops.

[0029] As a result, the displacement control piston 9 is displaced upwardly until it contacts with the inner wall of the needle accommodating chamber 5, and is kept at its uppermost position. The needle 3 is also displaced upwardly until it contacts with the displacement control piston 9. Therefore, the needle 3 is displaced by the displacement D2 from the condition shown in Fig. 4 or fully opens the nozzles 4, by the full displacement of the pressure control valve 14.

[0030] Figs. 6 to 11 shows various embodiments of the fuel injection.

[0031] In the embodiment shown in Fig. 6, the displacement VD of the pressure control valve 14 is made equal to and is temporarily kept at the small displacement SD, and then is made equal to and is temporarily

kept at the full displacement FD. Then, the valve displacement VD is returned to zero.

[0032] As a result, the needle displacement ND is first made equal to and is temporarily kept at the displacement D1, and thus the fuel injection with a fuel injection rate FIR being a low rate RL is performed. The needle displacement ND is then increased to D1 + D2, and thus the fuel injection with the fuel injection rate FIR being a high rate RH is performed.

[0033] If the fuel injection is started with the high injection rate RH, the amount of NO_x generated may increase and combustion noise may increase. The fuel injection shown in Fig. 6 is started with the low injection rate RL, and therefore, a generation of NO_x and the combustion noise, are suppressed.

[0034] In the embodiment shown in Fig. 7, the valve displacement VD is continuously increased from the zero-displaced position to the fully-displaced position, and kept at the full displacement FD for a preset time. Then, the valve displacement VD is returned to zero.

[0035] A displacing rate of the pressure control valve 14 is set so that the needle displacement ND is first made equal to and is temporarily kept at the displacement D1 and then the needle displacement ND is increased to D1 + D2, as in the embodiment shown in Fig. 6.

[0036] As a result, the fuel injection with a fuel injection rate FIR being the low rate RL is first performed, and then the fuel injection with the fuel injection rate FIR being the high rate RH is performed.

[0037] As described above, the pressure in the second pressure control chamber 8b is easily increased but is difficult to reduce, with respect to the pressure in the first pressure control chamber 8a. Therefore, even if the valve displacement VD is smaller than the small displacement SD, the needle 3 starts displacing upwardly when the upward force acting on the needle 3 exceeds the downward force acting on the needle 3. Further, even if the valve displacement VD is larger than the small displacement SD, the needle displacement ND is kept at the displacement D1 as long as the displacement control piston 9 is kept at its lowermost position. This means that no precise control of the displacement of the pressure control valve 14 is necessary in order to displace the needle 3 by the displacement D1.

[0038] Further, a fact that the pressure in the second pressure control chamber 8b is easily increased but is difficult to reduce will promote a rapid displacement of the needle 3 to close the nozzles 4.

[0039] Fig. 8 shows a low-rate fuel injection in which the displacement VD of the pressure control valve 14 is made equal to, and is temporarily kept at, the small displacement SD, and then is returned to zero. As a result, the needle displacement ND is made equal to, and is temporarily kept at, the displacement D1, and the fuel injection with the low rate RL is performed. The low-rate injection provides a fuel jet having a low penetration force.

[0040] As shown in Fig. 9, the valve displacement VD may be temporarily kept at a displacement larger than the small displacement SD, and then, may be temporarily kept at the small displacement SD, when the low-rate fuel injection should be performed. This promotes a rapid displacement of the needle 3 to open the nozzles 4.

[0041] Fig. 10 shows a high-rate fuel injection in which the displacement VD of the pressure control valve 14 is made equal to, and is temporarily kept at, the full displacement FD, and then is returned to zero. As a result, the needle displacement ND is made equal to, and is temporarily kept at, the displacement D1 + D2, and the fuel injection with the high rate RH is performed. The high-rate injection provides a jet of fuel having a high penetration force.

[0042] Fig. 11 shows an embodiment of fuel injections performed in one combustion cycle of an engine, including a main fuel injection and additional fuel injections which is performed in addition to the main fuel injection. The main fuel injection M in the form of the high-rate injection may be performed around the top dead center of the intake stroke of the engine.

[0043] Before the main fuel injection M, two additional injections are performed. Specifically, a first additional injection A1 in the form of the low-rate injection is performed in the intake stroke, and a second additional injection A2 in the form of the high-rate injection is then performed at the end of the compression stroke.

[0044] The first additional injection A1 in the form of the low-rate injection serves to form an air-fuel mixture spreading over the combustion chamber while preventing an adhesion of the additional fuel on the cylinder wall. The second additional injection A2 in the form of the high-rate injection serves to position the additional fuel near the fuel injected by the main fuel injection M, to thereby suppress generation of smoke.

[0045] After the main fuel injection M, two more additional injections are performed. Specifically, a third additional injection A3 in the form of the high-rate injection is performed at the top of the power stroke, and a fourth additional injection A4 in the form of the low-rate injection is then performed in the power or exhaust stroke.

[0046] The third additional injection A3 in the form of the high-rate injection serves to enhance mixing of an air-fuel mixture in the combustion chamber. The fourth additional injection A4 in the form of the low-rate injection serves to feed a reducing agent to a catalyst provided in the exhaust passage for reducing NO_x while preventing an adhesion of the additional fuel on the cylinder wall.

[0047] Note that, in the second and third additional injections A2, A3 shown in Fig. 11, the pressure control valve 14 is kept at the fully-displaced position for a very short time. Therefore, the needle displacement ND does not reach D1 + D2 and the fuel injection rate does not reach the high rate RH.

[0048] Fig. 12 shows another embodiment of the fuel injection, in which the first inflowing conduit 20a is omitted.

In this case, the fuel flows into the first pressure control chamber 8a via the first discharging conduit 11a.

[0049] In the embodiments described above, the needle displacement increases when the valve displacement increases. In other words, when the pressure control valve 14 displaces from the zero-displaced position to the fully-displaced position, it is prevented that the nozzle is first displaced to its fully-displaced position and then its intermediate position. Therefore, a rapid displacement of the needle 3 is ensured.

[0050] Further, in the above embodiments, in order to control a displacement of the needle 3 or a fuel injection rate, it is only required to control the pressures in the first and second pressure control chambers 8a and 8b, and it is unnecessary to drive the needle 3 directly or control the pressure fed to the fuel injector 1. In addition, the actuator 15 is connected to the pressure control valve 14 via the fuel-filled chamber 16, and therefore, no precise control of a displacement of the actuator 15 is necessary. Even if the actuator 15 undesirably extends or shrinks according to its temperature, an undesirable change of the pressures in the first and second pressure control chambers 8a and 8b is prevented.

[0051] Further, in the above embodiments, the fuel is fed to the fuel injector 1 at a constant fuel pressure. However, if a fuel pump which feeds the fuel to the fuel injector 1 is of an engine-driven type, the pressure of fuel supplied to the fuel injector 1 may vary according to the engine operating condition. In this case, if the fuel pressure becomes high, an amount of the actually injected fuel becomes large and, if the fuel pressure becomes low, the amount of the actually injected fuel becomes small.

[0052] In order to avoid this, the low-rate injection may be performed when the fuel pressure is higher than an upper threshold, and the high-rate injection is performed when the fuel pressure is lower than a lower threshold. This avoids an excess or a lack of fuel fed to the engine. Further, when the fuel pressure is high, it is unnecessary to discharge a part of fuel in the fuel injector 1 therefrom to reduce the amount of the actually injected fuel.

[0053] In order to judge whether the fuel pressure is higher than the upper threshold or is lower than the lower threshold, a pressure sensor may be provided in the common rail. Alternatively, it may be judged on the basis of the engine operating condition. Specifically, the fuel pressure will become high during a rapid deceleration just after a heavy-load operation of the engine.

[0054] In the above embodiments, the needle 3 closes the nozzles 4 when the pressure control valve 14 is in the zero-displaced position, partly opens the nozzles 4 when the valve 14 is in the intermediate position, and fully opens the nozzles 4 when the valve 14 is in the fully-displaced position. Alternatively, the needle 3 closes the nozzles 4 when the valve 14 is in the fully-displaced position, partly opens the nozzles 4 when the valve 14 is in the intermediate position, and fully opens the nozzles 4 when the valve 14 is in the zero-displaced

position.

[0055] Further, 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 inflowing conduit, and a single discharging conduit.

[0056] According to the present invention, it is possible to provide a fuel injector which is capable of rapidly displacing the needle.

[0057] A fuel injector comprising a housing with a nozzle, a needle movably accommodated in a needle accommodating chamber formed in the housing, for opening or closing the nozzle, a pressure control chamber defined between the needle and an inner wall of the needle accommodating chamber and filled with a fuel, a displacement of the needle depending on the fuel pressure in the pressure control chamber, a pressure control valve movably provided in the housing for controlling the fuel pressure in the pressure control chamber; and an actuator for controlling a displacement of the pressure control valve. The needle is displaced to a position in which it closes the nozzle when the pressure control valve is displaced to the zero-displaced position, is displaced to a position in which it partly opens the nozzle when the pressure control valve is displaced to an intermediate position, and is displaced to a position in which it fully opens the nozzle when the pressure control valve is displaced to a fully-displaced position.

Claims

1. A fuel injector comprising:

a housing with a nozzle;
a needle movably accommodated in a needle accommodating chamber formed in the housing, for opening or closing the nozzle;
a pressure control chamber defined between the needle and an inner wall of the needle accommodating chamber and filled with a fuel, a displacement of the needle depending on the fuel pressure in the pressure control chamber;
a pressure control valve movably provided in the housing for controlling the fuel pressure in the pressure control chamber; and
an actuator for controlling a displacement of the pressure control valve;

wherein the needle is displaced by a first displacement when the pressure control valve is displaced to the zero-displaced position,

wherein the needle is displaced by a second displacement when the pressure control valve is displaced to the fully-displaced position,

wherein the needle is displaced by a third displacement when the pressure control valve is dis-

placed to an intermediate position between the zero-displaced position and the fully-displaced position, and

wherein the third displacement is between the first and second displacements.

2. A fuel injector according to claim 1, wherein the needle closes the nozzle when it is displaced by the first displacement, wherein the needle partly opens the nozzle when it is displaced by the third displacement, and wherein the needle fully opens the nozzle when it is displaced by the second displacement.
3. A fuel injector according to claim 2, wherein a displacement control piston is movably accommodated in the pressure control chamber, 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, wherein a valve chamber filled with the fuel is formed in the housing to accommodate the pressure control valve therein, wherein a high fuel pressure source is connected to the second pressure control chamber and the valve chamber via second and third inflowing conduits respectively, and the first and second pressure control chambers are connected to the valve chamber via first and second discharging conduits, respectively, and wherein the pressure control valve controls a connection between the valve chamber and a relief conduit and a connection between the valve chamber and the high fuel pressure source.
4. A fuel injector according to claim 3, wherein the pressure control valve prevents communication between the valve chamber and the relief conduit and connects the valve chamber to the high fuel pressure source when it is displaced to the zero-displaced position, wherein the pressure control valve partly connects the valve chamber to the relief conduit and connects the valve chamber to the high fuel pressure source when it is displaced to the intermediate position, and wherein the pressure control valve connects the valve chamber to the relief conduit and prevents communication between the valve chamber and the high fuel pressure source when it is displaced to the fully-displaced position.
5. A fuel injector according to claim 3, wherein the first pressure control chamber is connected to the high fuel pressure source via a first inflowing conduit.
6. A fuel injector according to claim 5, wherein a flow resistance of the second inflowing conduit is set

smaller than that of the first inflowing conduit.

7. A fuel injector according to claim 3, wherein a flow resistance of the second discharging conduit is set larger than that of the first discharging conduit. 5
8. A fuel injector according to claim 3, wherein a discharge coefficient of the second discharging conduit in a direction from the second pressure control chamber to the valve chamber is set smaller than that in a direction from the valve chamber to the second pressure control chamber. 10
9. A fuel injector according to claim 3, wherein the high fuel pressure source comprises a fuel supply conduit extending the housing to the nozzle. 15
10. A fuel injector according to claim 2, wherein the pressure control valve is displaced to and temporarily maintained at the intermediate position so that the needle temporarily opens the nozzle partly, and is then displaced to the fully-displaced position so that the needle opens the nozzle fully, and is then returned to the zero-displaced position so that the needle closes the nozzle. 20
25
11. A fuel injector according to claim 2, wherein the pressure control valve is displaced from the zero-displaced position to the fully-displaced position continuously, with a displacing rate of the pressure control valve being set so that the needle temporarily opens the nozzle partly and then opens the nozzle fully. 30
12. A fuel injector according to claim 2, wherein the fuel injector selectively performs one of a low-rate fuel injection in which the pressure control valve is displaced to the intermediate position and is then returned to the zero-displaced position, and a high-rate fuel injection in which the pressure control valve is displaced to the fully-displaced position and is then returned to the zero-displaced position. 35
40
13. A fuel injector according to claim 12, wherein, before a main fuel injection, the fuel injector additionally performs the low-rate fuel injection and the high-rate fuel injection, in turn. 45
14. A fuel injector according to claim 12, wherein, after a main fuel injection, the fuel injector additionally performs the high-rate fuel injection and the low-rate fuel injection, in turn. 50
15. A fuel injector according to claim 12, wherein, when the fuel injector should perform the low-rate fuel injection, the pressure control valve is temporarily displaced by a displacement larger than a displacement required for the intermediate position. 55

16. A fuel injector according to claim 12, wherein, when the pressure of fuel supplied to the fuel injector is higher than an upper threshold, the fuel injector performs the low-rate fuel injection.

17. A fuel injector according to claim 12, wherein when the pressure of fuel supplied to the fuel injector is lower than a lower threshold, the fuel injector performs the high-rate fuel injection.

Fig.1

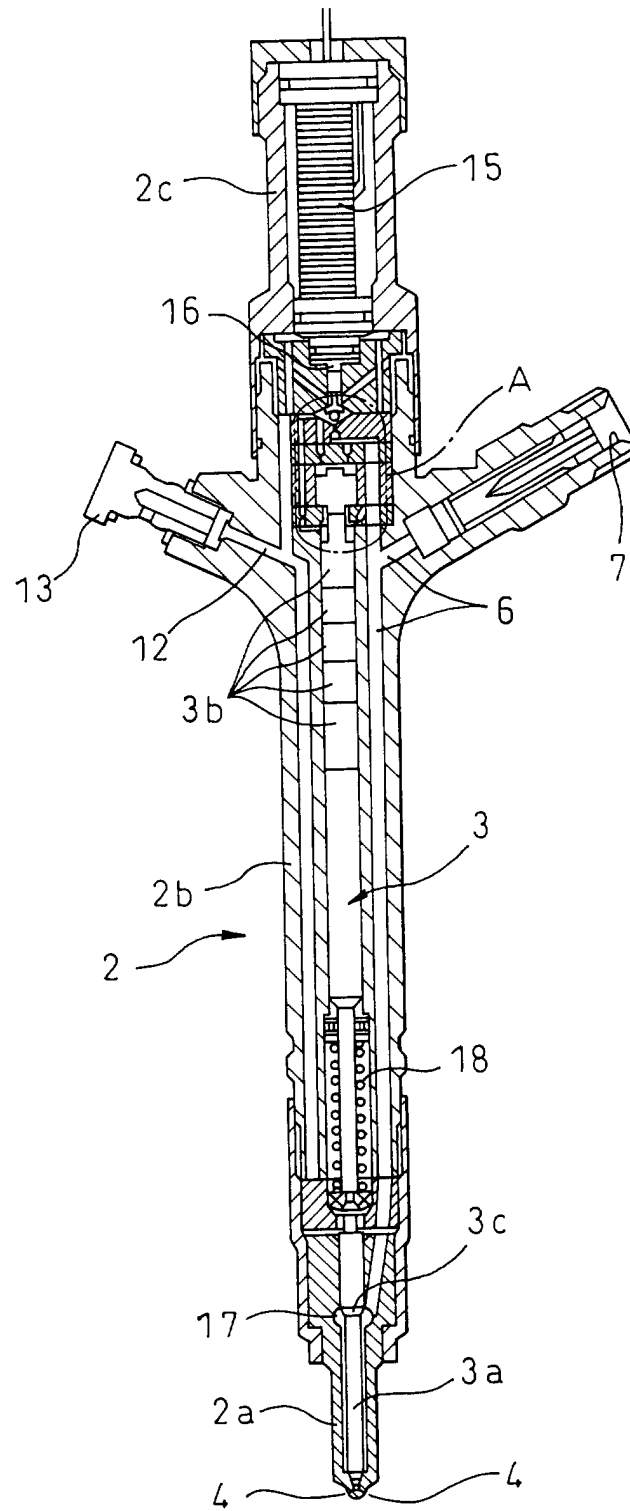


Fig. 2

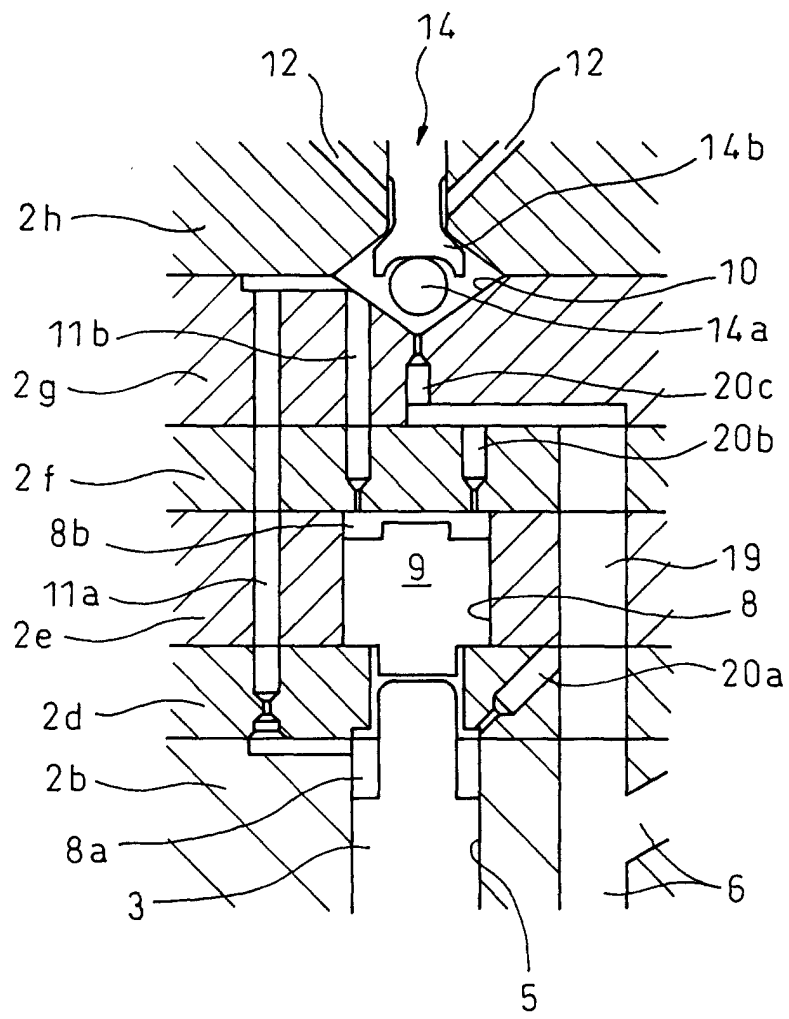


Fig. 3

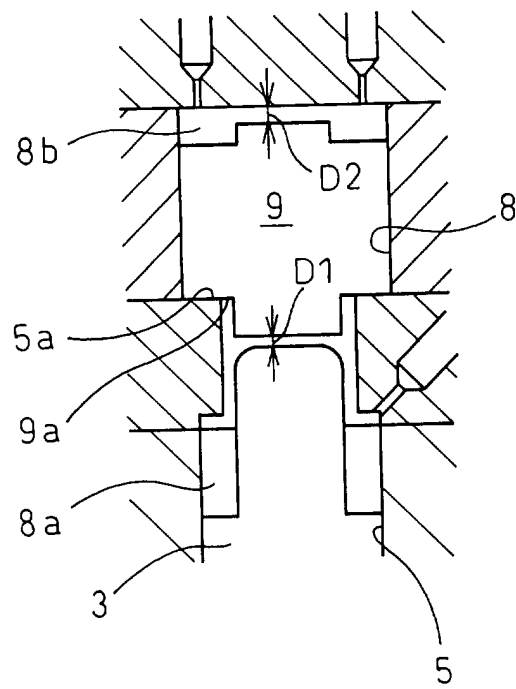


Fig.4

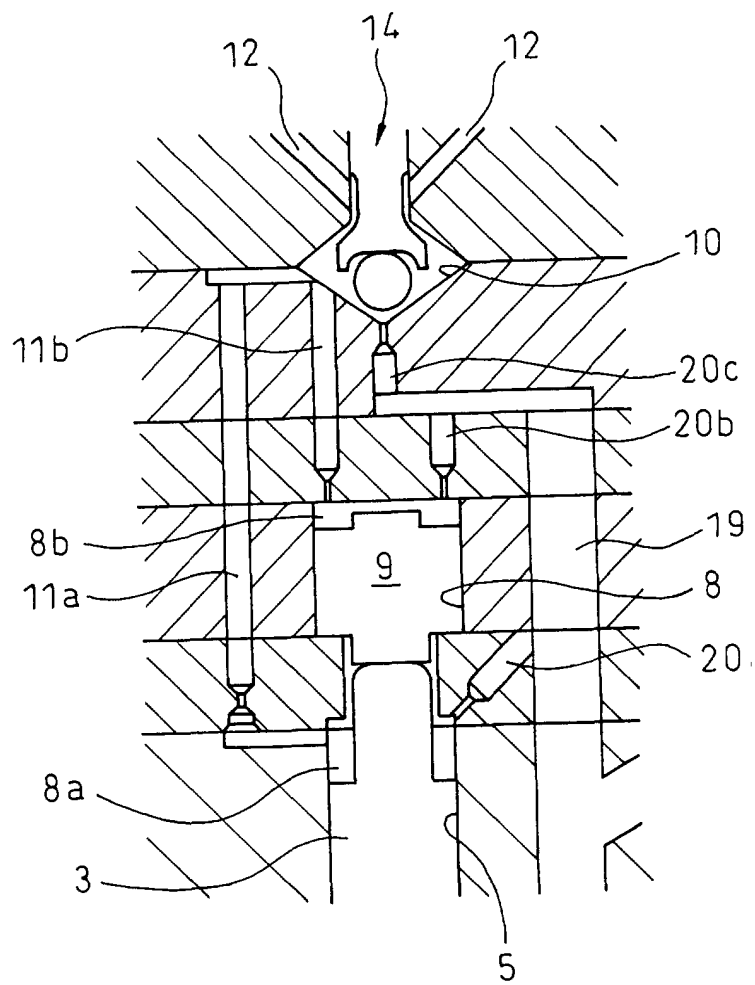


Fig. 5

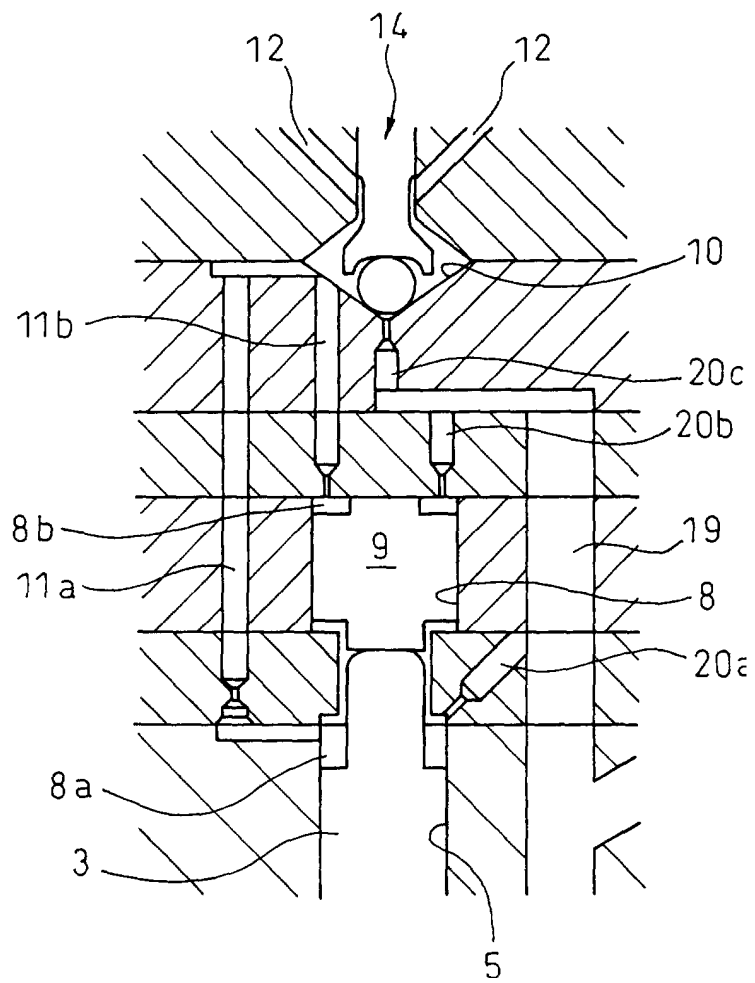


Fig.6

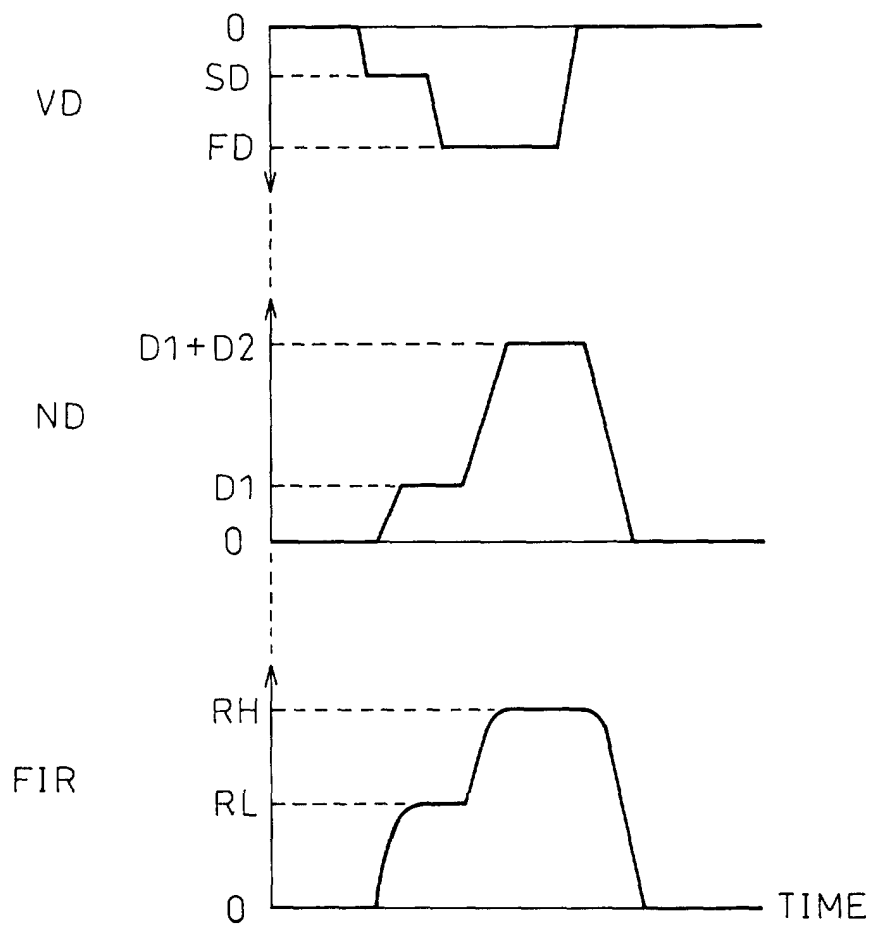


Fig.7

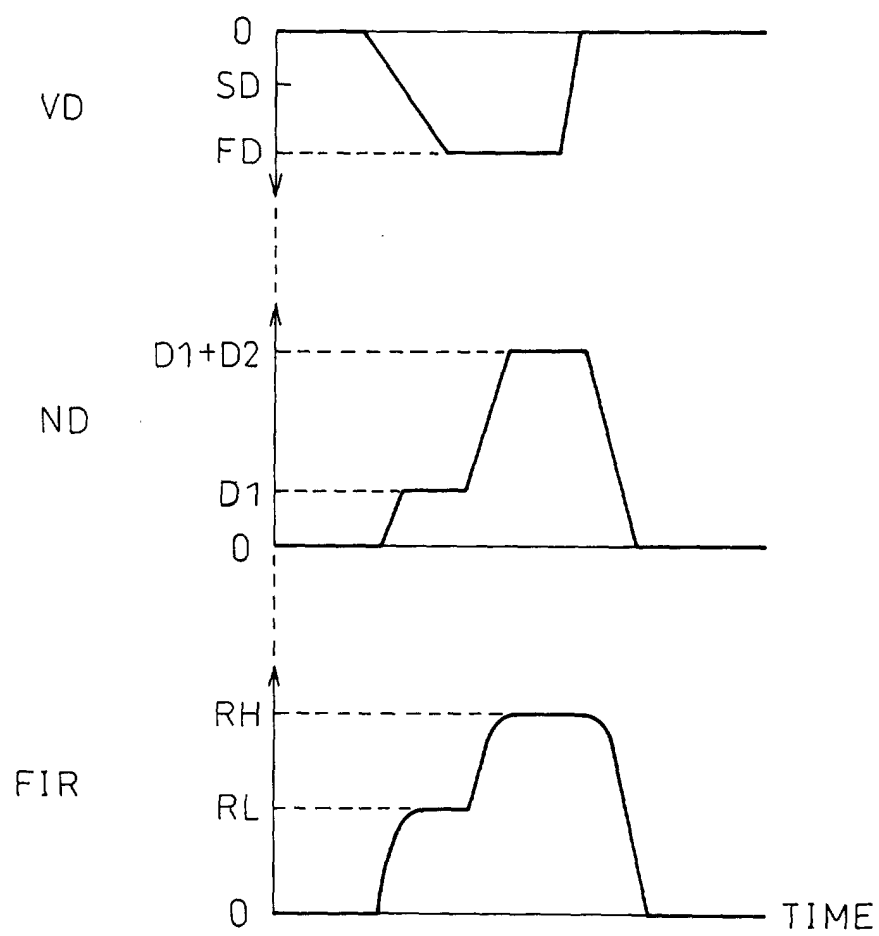


Fig. 8

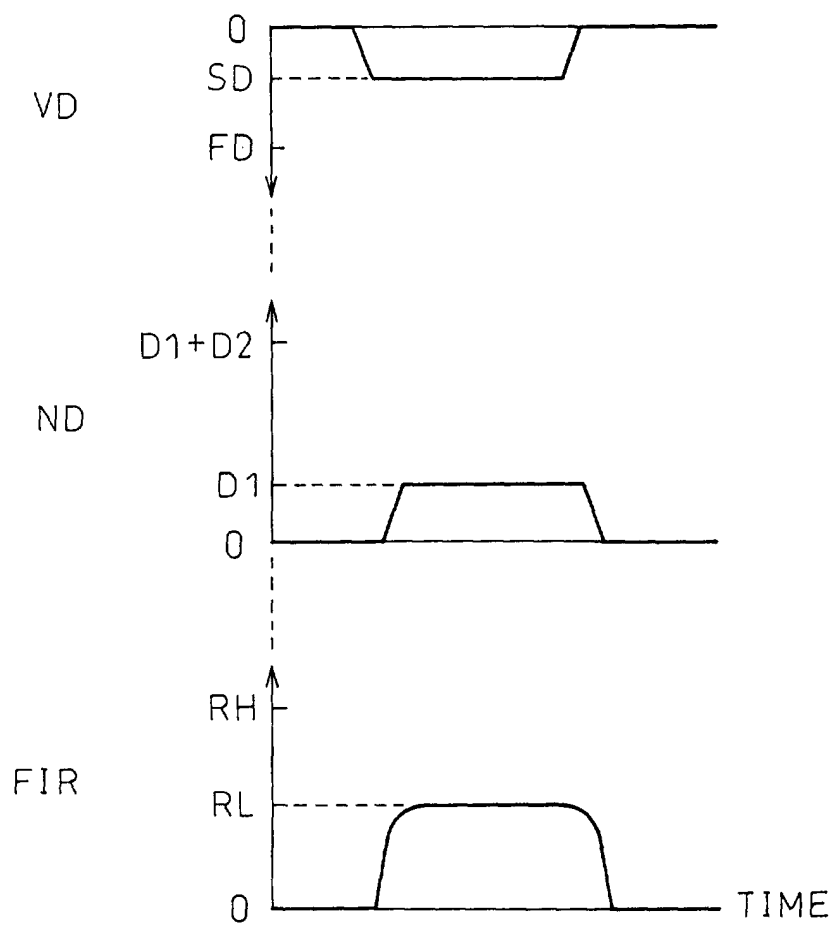


Fig.9

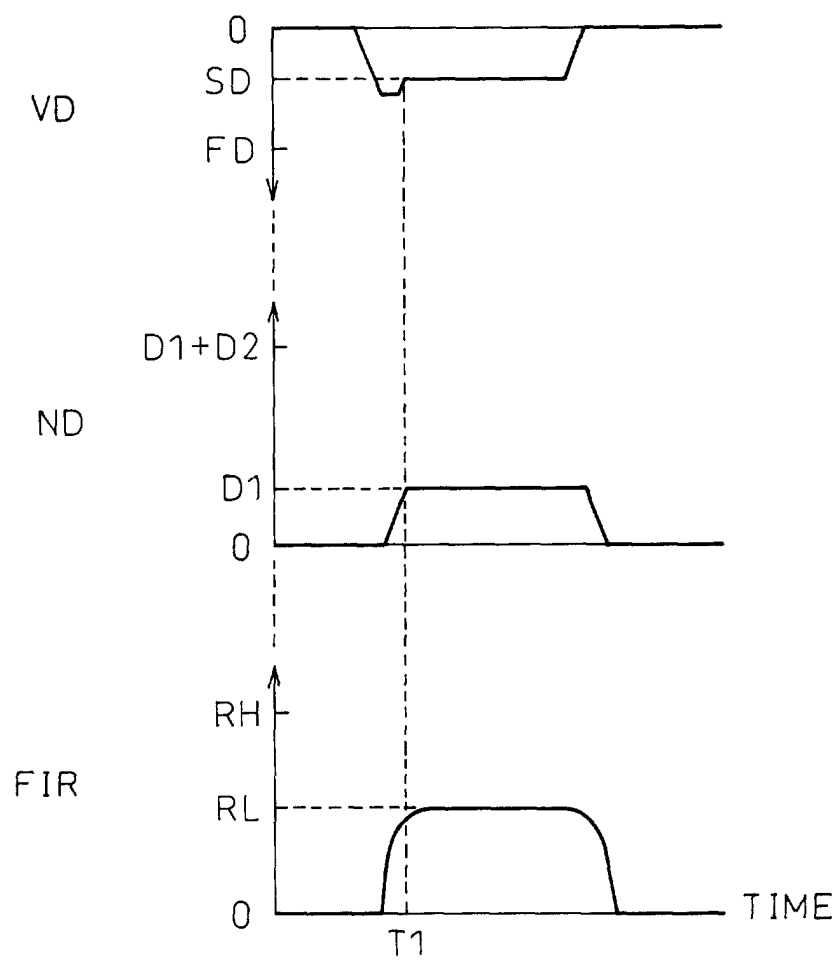


Fig.10

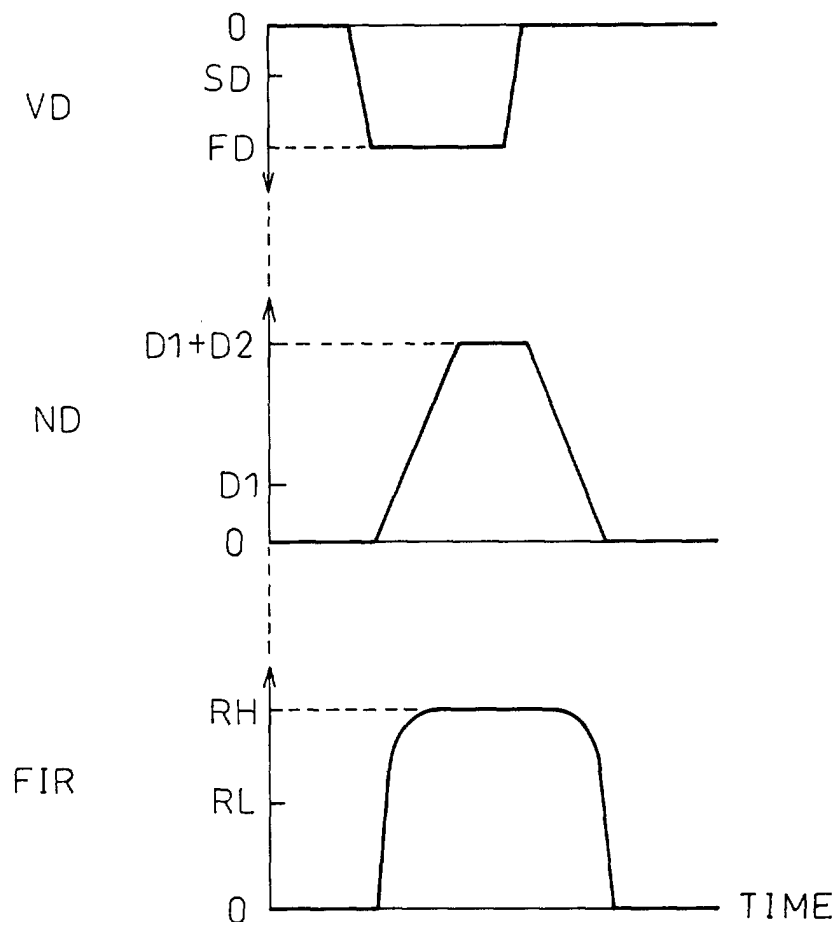


Fig.11

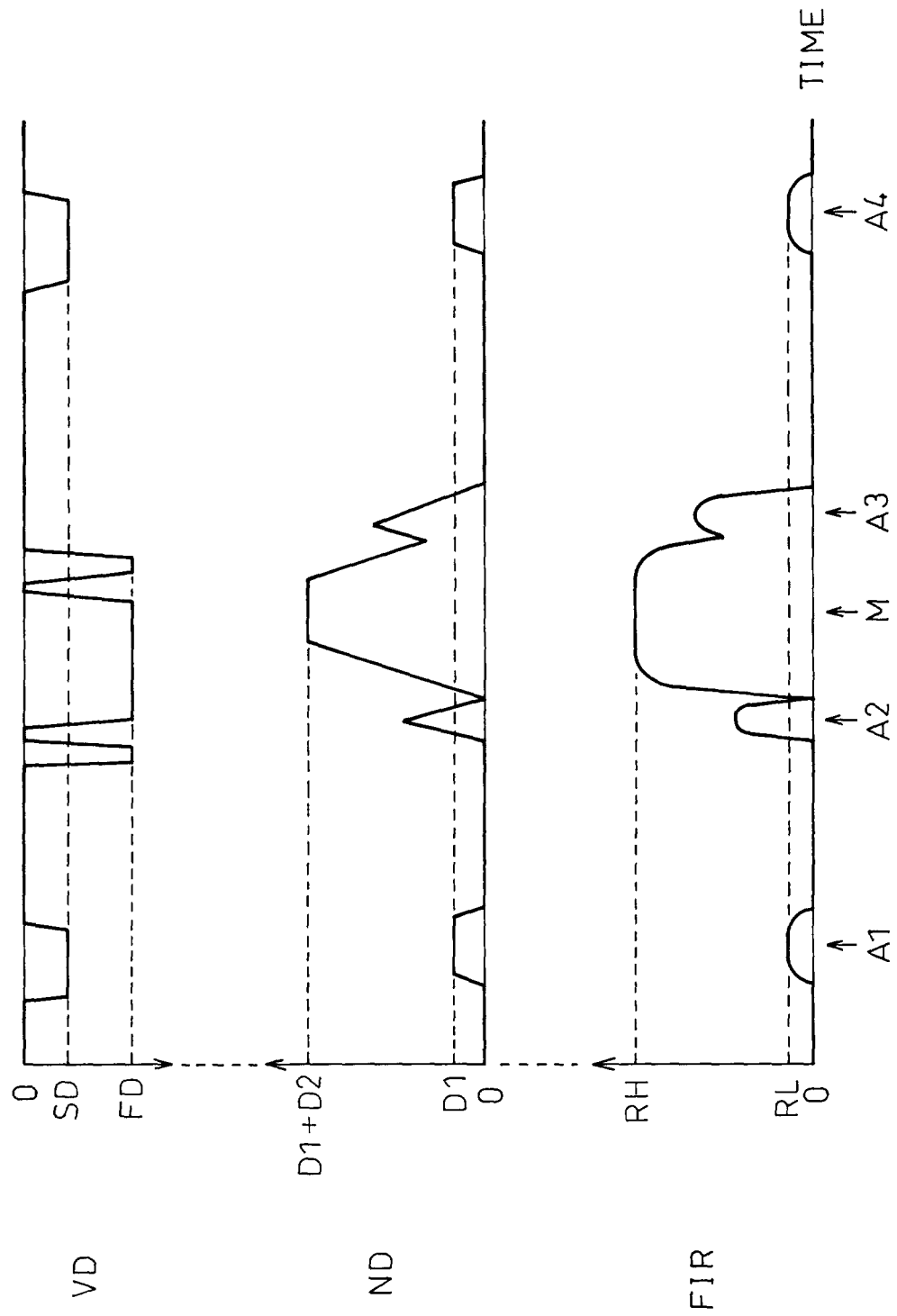


Fig.12

