(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 707 799 A1

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
**04.10.2006 Bulletin 2006/40**

(21) Application number: **06110896.5**

(22) Date of filing: **09.03.2006**

(51) Int Cl.:
***F02M 59/46*** *(2006.01)* ***F02M 63/02*** *(2006.01)*
***F02M 59/44*** *(2006.01)*

(84) Designated Contracting States:
**AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IS IT LI LT LU LV MC NL PL PT RO SE SI SK TR**
Designated Extension States:
**AL BA HR MK YU**

(30) Priority: **30.03.2005 JP 2005098583**
**24.11.2005 JP 2005339003**

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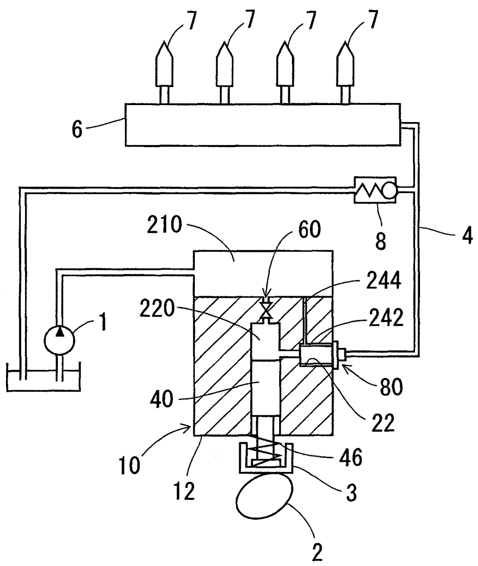
(54) **Fuel pump having plunger and fuel supply system using the same**

(57) A delivery valve (80) is connected to a discharge passage (230), through which fuel in a compression chamber (220) is discharged. The delivery valve (80) is screwed to a mount hole (22) formed in the cylinder (12). A communication passage (240) is formed in a body (82) to extend through the sidewall between a screwed part, in which the mount hole (22) and the body (82) are screwed to each other, and a gasket (88). A small clearance (242) is formed between an inner peripheral surface (23) of the mount hole (22) and an outer peripheral surface (83) of the body (82). The communication passage (240) provides communication between a fuel passage (232) downstream of a valve seat member (87) and the clearance (242). The clearance (242) communicates with the suction chamber (210) through a return passage (240, 270, 290) formed in the cylinder (12).

**FIG. 1**

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## Description

**[0001]** The present invention relates to a fuel pump, which pressurizes fuel in a compression chamber using a plunger in order to supply the fuel, and a fuel supply system using the fuel pump.

**[0002]** According to US 2003/0161746A1 (JP-A-2001-295770), a high-pressure fuel pump includes a plunger that reciprocates to pressurize fuel drawn into a compression chamber in order to supply the fuel into a delivery pipe connected to a fuel injection valve. The fuel supplied to the delivery pipe is jetted into a combustion chamber of an internal combustion engine from the fuel injection valve.

**[0003]** Such a high-pressure fuel pump includes a delivery valve mounted downstream of the compression chamber. The delivery valve is opened when fuel pressure in the compression chamber increases to be equal to or greater than predetermined pressure, thereby supplying the fuel in the compression chamber into the delivery pipe. The delivery valve also serves as a check valve that restricts counterflow of fuel from the delivery pipe into the compression chamber.

**[0004]** When a fuel injection valve is stopped by fuel cut in operation of an engine or by stoppage of the engine, the downstream side of the high-pressure fuel pump is blocked by a delivery valve and the fuel injection valve. When a relief valve is provided to restrict abnormal rise in fuel pressure on the downstream side of the high-pressure fuel pump, the relief valve further blocks the downstream side of the high-pressure fuel pump. Thus, fuel downstream of the high-pressure fuel pump is maintained in high pressure. Such fuel pressure is a control pressure when the fuel injection valve is stopped. In addition, in the case where the engine has been adequately warmed, fuel pressure further rises due to heat transmitted from the engine.

**[0005]** When fuel pressure downstream of the high-pressure fuel pump is maintained high, upstream of the fuel injection valve is also maintained high. In this condition, fuel may leak from a valve portion of the fuel injection valve, which is maintained in a closed state during stoppage of the engine, into a combustion chamber. When fuel leaks into the combustion chamber during stoppage of the engine, a large amount of an unburned fuel ingredient such as hydrocarbon may be discharged into exhaust gases at the start of the engine. In addition, when fuel injection is restarted from a state of fuel cut in the operation of the engine, it is desired that an amount of fuel jetted from the fuel injection valve be small to be adapted to the operating state. However, when fuel upstream of the fuel injection valve is maintained in high pressure, a large amount of fuel may be jetted from the fuel injection valve in the restart of fuel injection. Consequently, engine output may rapidly increase, and a shock may be applied on a drive system of the engine.

**[0006]** Hereupon, a small passage such as a groove may be provided in a seat surface of a valve portion of a delivery valve or a relief valve in order to introduce fuel downstream of the high-pressure fuel pump to a low-pressure side during stoppage of the fuel injection valve. In this structure, fuel pressure on the downstream side of the high-pressure fuel pump can be reduced during stoppage of the fuel injection valve.

**[0007]** When the passage provided on the seat surface of the valve portion of the delivery valve or the relief valve is excessively large in area, an amount of fuel returning from the downstream of the high-pressure fuel pump to the low-pressure side may increase. Consequently, the amount of fuel returning to the low-pressure side may increase during the operation of the fuel injection valve. Accordingly, the high-pressure fuel pump needs to additionally discharge the amount of the fuel returning to the low pressure side in order to make up for the amount of the return fuel. As a result, discharge capacity of the high-pressure fuel pump needs to be increased.

**[0008]** In view of the foregoing and other problems, it is an object of the present invention to produce a fuel pump capable of reducing fuel pressure downstream of the fuel pump while reducing an amount of fuel returning to a low-pressure side from the downstream of a delivery valve of the fuel pump. It is another object of the present invention to produce a fuel supply system using the fuel pump.

**[0009]** According to one aspect of the present invention, a fuel pump, which supplies fuel to a delivery pipe, includes a pump housing, a plunger, a delivery valve, and at least one functional component. The pump housing has a compression chamber and at least one mount hole. The plunger is movable in the pump housing. The plunger is adapted to pressurizing fuel drawn into the compression chamber. The delivery valve communicates the compression chamber with the delivery pipe when fuel pressure in the compression chamber is equal to or greater than a threshold. At least one functional component is provided to the at least one mount hole of the pump housing. The at least one functional component and the at least one mount hole define at least one clearance therebetween. Fuel on a downstream side of the delivery valve returns into a low-pressure side thereof through the at least one clearance.

**[0010]** Thus, fuel pressure downstream of the delivery valve can be reduced, even when fuel is not discharged from the delivery pipe downstream of the delivery valve.

**[0011]** The above and other objects, features and advantages of the present invention will become more apparent from the following detailed description made with reference to the accompanying drawings. In the drawings:

FIG. 1 is a schematic view showing a structure of a fuel supply system including a high-pressure fuel pump, according to a first embodiment of the present invention;

FIG. 2A is a partially cross sectional side view showing the high-pressure fuel pump and a delivery valve, and FIG. 2B is an enlarged cross sectional side view showing the delivery valve, according to the first embodiment;

FIG. 3 is a partially cross sectional side view showing the high-pressure fuel pump and a piping joint, according to the first embodiment;

FIG. 4 is a partially cross sectional view taken along the line IV-IV in FIG. 2A;

FIG. 5A is a partially cross sectional side view showing a high-pressure fuel pump and a relief valve, and FIG. 5B is an enlarged cross sectional side view showing the relief valve, according to a second embodiment of the present invention;

FIG. 6 is a cross sectional view taken along the line VI-VI in FIG. 5A;

FIG. 7 is a partially cross sectional side view showing a high-pressure fuel pump including a delivery valve and a relief valve, according to a third embodiment of the present invention;

FIG. 8 is a cross sectional view taken along the line VIII-VIII in FIG. 7;

FIG. 9 is an enlarged cross sectional side view showing the delivery valve according to the third embodiment;

FIG. 10 is an enlarged cross sectional side view showing the relief valve according to the third embodiment;

FIG. 11 is a schematic view showing a structure of a fuel supply system including a high-pressure fuel pump, according to a fourth embodiment of the present invention;

FIG. 12 is a partially cross sectional side view showing a high-pressure fuel pump according to a fifth embodiment of the present invention;

FIG. 13 is a partially cross sectional side view showing a high-pressure fuel pump according to a sixth embodiment of the present invention;

FIG. 14 is a partially cross sectional side view showing a high-pressure fuel pump according to a seventh embodiment of the present invention; and

FIG. 15 is a partially cross sectional side view showing a high-pressure fuel pump according to an eighth embodiment of the present invention.

(First Embodiment)

**[0012]** As follows, a high-pressure fuel pump 10 in the first embodiment is described in reference to FIGS. 1, 2A, 2B, 3, and 4. FIG. 2A is the view taken along the line IIA- IIA in FIG. 4. FIG. 3 is the view taken along the line III - III in FIG. 4.

**[0013]** As shown in FIG. 1, a fuel supply system includes a high-pressure fuel pump 10. In addition, the fuel supply system is a direct injection gasoline supply system that jets fuel directly into cylinders of a gasoline engine. The high-pressure fuel pump 10 supplies fuel into fuel injection valves 7.

**[0014]** The high-pressure fuel pump 10 uses an electromagnetic driven type metering valve (solenoid valve) 60 to provide and interrupt communication between a suction chamber 210 and a compression chamber 220. Fuel from a low-pressure fuel pump 1 is supplied into the suction chamber 210. A plunger 40 reciprocates with rotation of a cam 2 to pressurize fuel drawn into the compression chamber 220. Fuel pressurized in the compression chamber 220 passes from a delivery valve 80 to be supplied to a delivery pipe 6 through a fuel pipe 4 on the downstream side of the high-pressure fuel pump 10. Fuel injection valves 7 are mounted to the delivery pipe 6 to jet fuel, which is accumulated in the delivery pipe 6, into combustion chambers of an engine. A relief valve 8 is mounted to the fuel pipe 4 on the downstream side of the high-pressure fuel pump 10. The relief valve 8 restricts abnormal rise in fuel pressure on the downstream side of the high-pressure fuel pump 10.

**[0015]** Subsequently, the construction of the high-pressure fuel pump 10 is described. The high-pressure fuel pump 10 is constructed of a cylinder 12, a housing cover 30, a plunger 40, a piping joint 50, the metering valve 60, the delivery valve 80, and the like.

**[0016]** The cylinder 12 and the housing cover 30 form a pump housing. The cylinder 12 is formed of a magnetic material such as a martensitic stainless steel. The cylinder 12 supports the plunger 40 to permit reciprocation thereof. The cylinder 12 has a sliding portion 14, on which the plunger 40 slides. The sliding portion 14 is hardened by induction hardening or the like. Functional components of the high-pressure fuel pump 10 are mounted directly on the cylinder 12. The functional components of the high-pressure fuel pump 10 include the piping joint 50, the metering valve 60, the delivery valve 80, and the like. The piping joint 50 forms a fuel inlet. The delivery valve 80 forms a fuel outlet. The cylinder 12 constructs a housing body of the high-pressure fuel pump 10.

**[0017]** In addition, the cylinder 12 has an introduction passage 202, a suction passage 212, the compression chamber 220, a relief passage 222, a discharge passage 230, a return passage 244, and the like. The suction chamber 210 is formed between the cylinder 12 and the housing cover 30.

**[0018]** The sliding portion 14 of the cylinder 12 supports the plunger 40 to permit reciprocation thereof. The compression chamber 220 is formed on one end side of the plunger 40 with respect to the direction, in which the plunger 40 reciprocates. A head 42 formed on the other end side of the plunger 40 joins to a spring seat 44. A spring 46 is interposed between the spring seat 44 and the cylinder 12. The spring seat 44 is pushed against an inner wall of a bottom of a tappet 3 (FIG. 1) by the bias of the spring 46. As the cam 2 (FIG. 1) rotates, an outer wall of the bottom of the tappet 3 slides on the cam 2 whereby the plunger 40 reciprocates. An oil seal 48 seals between an outer peripheral surface of the plunger 40 on the side of the head 42 and an inner peripheral surface of the cylinder 12, which receives the plunger 40 therein. The oil seal 48 restricts intrusion of oil into the compression chamber 220 from the inside of an engine, and restricts leakage of oil into the engine from the inside of the compression chamber 220. Fuel leaking from a sliding part, in which the plunger 40 and the cylinder 12 slide on each other, toward the oil seal 48 returns to the low-pressure side introduction passage 202 from the relief passage 222. Thereby, high fuel pressure is restricted from being applied on the oil seal 48.

**[0019]** As shown in FIG. 3, a body 52 of the piping joint 50 and the cylinder 12 are screwed to each other, whereby the piping joint 50 is mounted to a mount hole 16 formed in the cylinder 12. A fuel passage 200 being communicated with the introduction passage 202 is formed in the body 52 of the piping joint 50, and a fuel filter 54 is mounted in the fuel passage 200.

**[0020]** The metering valve 60 is constructed of a valve member 62, a guide 64, a spring 66, a valve seat member 68, an electromagnetic drive unit 70, and the like. The valve member 62 is formed by applying coating of high hardness on a cup-shaped magnetic material or on a cup-shaped surface of a magnetic material. The valve member 62 is guided by the guide 64 to be able to reciprocate. The spring 66 biases the valve member 62 toward the valve seat member 68, which is mounted on the side of the suction chamber 210 with respect to the valve member 62. When the valve member 62 is seated on the valve seat member 68, communication between the suction chamber 210 and the suction passage 212 is interrupted. The valve seat member 68 is screwed to the cylinder 12.

**[0021]** The electromagnetic drive unit 70 of the metering valve 60 is formed by insert-molding a center core 74 and a coil portion 76 into a resin portion 72. The center core 74 and the coil portion 76 are arranged outwardly eccentric from the valve member 62. The center core 74 and the coil portion 76 are fitted into a recess 18 of the cylinder 12 provided on the outer peripheral side of the compression chamber 220 on the opposite side of the suction chamber 210 with respect to the valve member 62. When the coil portion 76 is electrically turned ON, a magnetic attraction force acts between an attracting portion 20 of the cylinder 12 and the valve member 62. The attracting portion 20 of the cylinder 12 is provided on the opposite side of the valve seat member 68 with respect to the valve member 62.

**[0022]** As referred to FIGS. 2A, 2B, the delivery valve 80 forming a fuel outlet of the high-pressure fuel pump 10 is constructed of a body 82, a valve member 84, a spring 85, a spring seat 86, and a valve seat member 87. The delivery valve 80 is connected to a discharge passage 230, through which fuel in the compression chamber 220 is discharged. Female threads are formed on an inner peripheral surface 23 of a mount hole 22 formed in the cylinder 12. Male threads are formed on an outer peripheral surface 83 of the body 82. The female threads of the mount hole 22 and male threads are screwed to each other, whereby the delivery valve 80 is mounted to the mount hole 22. A gasket 88 seals between the mount hole 22 and the delivery valve 80 inside the cylinder 12 with respect to a screwed part, in which the mount hole 22 and the delivery valve 80 are screwed to each other. An O-ring 89 seals between the mount hole 22 and the delivery valve 80 outside the cylinder 12 with respect to the screwed part.

**[0023]** The spring 85 is latched at one end on the spring seat 86 to bias the valve member 84 in the direction, in which the valve member 84 is seated on the valve seat member 87. The body 82 is formed with a fuel passage 232, such that communication between the discharge passage 230 and the fuel passage 232 is interrupted when the valve member 84 is seated on the valve seat member 87. A communication passage 240 being a return passage is formed in the body 82 to extend through the sidewall between the screwed part, in which the mount hole 22 and the body 82 are screwed to each other, and the gasket 88. The communication passage 240 communicates with the fuel passage 232 downstream of the valve seat member 87. The delivery valve 80 is provided with an inlet of a return passage. A small clearance 242 is defined between the inner peripheral surface 23 of the mount hole 22 and the outer peripheral surface 83 of the body 82 on the side of gasket 88. The small clearance 242 is formed in the screwed part, in which the mount hole 22 and the body 82 are screwed to each other, including a location, in which the communication passage 240 is formed. The clearance 242 communicates with the communication passage 240, thereby communicating with the fuel passage 232 downstream of the valve seat member 87. In addition, the clearance 242 communicates with the suction chamber 210 through the return passage 244 formed in the cylinder 12. Accordingly, the fuel passage 232 downstream of the valve seat member 87 communicates with the suction chamber 210 on the low-pressure side through the clearance 242.

**[0024]** Subsequently, an operation of the high-pressure fuel pump 10 is described.

**[0025]** As follows, a suction stroke is described.

**[0026]** The plunger 40 descends, so that pressure in the compression chamber 220 decreases in the suction stroke. In this suction stroke, differential pressure, which is applied to the valve member 62 from the suction chamber 210 upstream of the valve member 62 and the compression chamber 220 downstream thereof, varies. Specifically, a seating force is applied to the valve member 62 by fuel pressure in the compression chamber 220 in a seating direction, in which the valve member 62 is seated on the valve seat member 68. A lifting force is applied to the valve member 62 by fuel pressure in the suction chamber 210 in a lifting direction, in which the valve member is spaced from the valve seat member 68. When the sum of the seating force applied to the valve member 62 and the bias of the spring 66 in the seating direction becomes less than the lifting force applied on the valve member 62 in the lifting direction, the valve member 62 is spaced from the valve seat member 68. Thus, the valve member 62 is latched on the attracting portion 20 of the cylinder 12. The attracting portion 20 of the cylinder 12 is provided on the opposite side of the valve seat member 68 with respect to the valve member 62. Thereby, fuel is drawn from the suction chamber 210 into the compression chamber 220 through the suction passage 212.

**[0027]** In a state, in which the valve member 62 and the attracting portion 20 of the cylinder 12 abut against each other before the plunger 40 reaches the bottom dead center, the coil portion 76 is electrically turned ON. In this condition, the valve member 62 and the cylinder 12 abut against each other, so that the magnetic attraction force required to maintain a valve opened state, in which the valve member 62 is latched on the attracting portion 20, may be small in the metering valve 60.

**[0028]** As follows, a return stroke is described.

**[0029]** The magnetic attraction force acts between the attracting portion 20 and the valve member 62, even when the plunger 40 ascends toward the top dead center from the bottom dead center in a state, in which the coil portion 76 is electrically turned ON is maintained. Therefore, the valve member 62 is sustained in a valve opening position, in which it is latched on the attracting portion 20. Thereby, fuel is pressurized in the compression chamber 220 as the plunger 40 ascends, and the fuel passes through the suction passage 212 to return from the metering valve 60 into the suction chamber 210.

**[0030]** As follows, a compression stroke is described.

**[0031]** When the coil portion 76 is electrically turned OFF in the return stroke, the valve member 62 and the attracting portion 20 terminate generating the magnetic attraction force therebetween. Consequently, the sum of the force applied on the valve member 62 by fuel pressure in the compression chamber 220 and the bias of the spring 66 in the seating direction becomes greater than the force applied on the valve member 62 in the lifting direction by fuel pressure in the suction chamber 210. Consequently, the valve member 62 is seated on the valve seat member 68 by the differential pressure, so that communication between the suction chamber 210 and the suction passage 212 is interrupted. In this state, when the plunger 40 ascends further toward the top dead center, fuel in the compression chamber 220 is pressurized, so that fuel pressure rises. When fuel pressure in the compression chamber 220 increases to be equal to or greater than predetermined pressure, the valve member 84 is spaced from the valve seat member 87 against the bias of the spring 85, so that the delivery valve 80 is opened. Thereby, fuel pressurized in the compression chamber 220 passes from the discharge passage 230 to be discharged from the delivery valve 80 through the fuel passage 232. The fuel discharged from the delivery valve 80 is fed to the delivery pipe 6 shown in FIG. 1 to be accumulated therein, and is supplied into the fuel injection valves 7.

**[0032]** By repeating the above strokes, the high-pressure fuel pump 10 pressurizes fuel drawn thereinto to discharge the fuel. An amount of fuel as discharged using the high-pressure fuel pump 10 is metered by controlling a period, in which the coil portion 76 of the metering valve 60 is electrically turned ON.

**[0033]** The fuel passage 232 downstream of the valve seat member 87 in the delivery valve 80 communicates with the suction chamber 210 through the clearance 242. Therefore, fuel present between the delivery valve 80 and the delivery pipe 6 regularly returns to the suction chamber 210 on the low-pressure side through the clearance 242.

**[0034]** Consequently, when the fuel injection valves 7 are stopped by fuel cut during the operation of the engine, for example, fuel pressure downstream of the high-pressure fuel pump 10 decreases. In this condition, fuel pressure upstream of the fuel injection valves 7 decreases. Thereby, an amount of fuel jetted from the fuel injection valves 7 can be reduced, so that the amount of fuel jetted from the fuel injection valves 7 can be adapted to the operating state when the operation of the fuel injection valves 7 is restarted. Thus, engine output can be restricted from rapidly increasing, so that a drive system of the engine can be protected from a shock.

**[0035]** In addition, fuel pressure upstream of the fuel injection valves 7 also decreases when the fuel injection valves 7 are stopped by engine stoppage, for example. Therefore, fuel can be restricted from leaking into a combustion chamber of the engine through a valve portion of the fuel injection valves 7. Thereby, an unburned fuel component, such as HC, contained in exhaust gases can be reduced when the engine is restarted.

**[0036]** In the above structure, the inner peripheral surface 23 of the mount hole 22 and the outer peripheral surface 83 of the body 82 of the delivery valve 80 are substantially circular in shape. Therefore, the mount hole 22 and the body 82 can be easily manufactured with high accuracy by a machining work, for example. Accordingly, the clearance 242 formed between the mount hole 22 and the body 82 can be adjusted with high accuracy. Thus, an amount of fuel returning to the suction chamber 210 on the low-pressure side through the clearance 242 can be restricted from excessively increasing. Thereby, the high-pressure fuel pump 10 can be restricted from increasing in discharge capacity in order to make up for a flow rate of fuel returning to the suction chamber 210 through the clearance 242.

**[0037]** In addition, the clearance 242 is defined in the mount hole 22, through which the delivery valve 80 is mounted into the cylinder 12. The delivery valve 80 is one of the functional components of the high-pressure fuel pump 10. That is, the clearance 242 is formed by the components necessary for the high-pressure fuel pump 10. Therefore, machining work can be restricted from increasing in order to introduce return fuel to the low-pressure side, irrespective of forming the clearance 242. Besides, the number of components can be restricted from increasing, irrespective of forming the clearance 242.

**[0038]** In addition, the communication passage 240 is formed in the body 82 of the delivery valve 80 to provide the inlet of the return passage on the delivery valve 80.

Therefore, machining work need not be made in a downstream component such as the fuel pipe 4 and/or the delivery pipe 6 on the downstream side of the high-pressure fuel pump 10 in order to form a return passage in this component.

**[0039]** Hereupon, fuel on the downstream side of the delivery valve 80 may be introduced to a component on the low-pressure side outside of the high-pressure fuel pump 10. In this structure, components need to be additionally provided to form a return passage. In addition, a sealing structure needs to be additionally provided. Furthermore, the return passage may become lengthy.

**[0040]** However, in the first embodiment, return fuel flows from the communication passage 240, which is provided in the delivery valve 80, into the suction chamber 210 inside the high-pressure fuel pump 10 after passing through the clearance 242, which is formed between the mount hole 22 and the delivery valve 80, and the return passage 244 formed in the cylinder 12. Therefore, components constructing a return passage and a sealing structure need not be additionally provided. Further, the return passage constructed of the communication passage 240 and the return passage 244 is short in total length. Accordingly, machining work can be easily made to form the return passage.

**[0041]** A clearance may be formed between the outer periphery of the metering valve 60 and the receiving hole, in which the metering valve 60 is accommodated in the cylinder 12. In this structure, fuel downstream of the delivery valve 80 may be returned to the low pressure side such as the suction chamber 210 through the clearance between the metering valve 60 and the receiving hole of the cylinder 12. Specifically, the clearance between the metering valve 60 and the receiving hole of the cylinder 12 may communicate the communication passage 240 of the delivery valve 80 with the suction chamber 210. Thus, fuel downstream of the delivery valve 80 may be returned to the low pressure side such as the suction chamber 210 through the communication passage 240, the clearance 242, and the clearance between the metering valve 60 and the receiving hole of the cylinder 12. In this case, the receiving hole of the cylinder 12 serves as the mount hole.

(Second Embodiment)

**[0042]** As follows, a high-pressure fuel pump 90 in the second embodiment is described in reference to FIGS. 5A, 5B, and 6. FIG. 5A is the view taken along the line VA-VA in FIG. 6.

**[0043]** As shown in FIGS. 5A, 5B, and 6, with the high-pressure fuel pump 90 in the second embodiment, a relief valve 100 is mounted to a mount hole 24 formed in the cylinder 12. In this construction, the relief valve 8 (FIG. 1), which is mounted to the fuel pipe 4 on the downstream side of the high-pressure fuel pump 90, may be omitted. The relief valve 100 restricts abnormal rise in fuel pressure on the downstream side of the high-pressure fuel pump 90. The relief valve 100 serves as one of the functional components of the high-pressure fuel pump 90.

**[0044]** The relief valve 100 is constructed of a body 102, a ball 104, a guide 105, a spring 106, and a valve seat member 107. The relief valve 100 is connected to a discharge passage 250 communicated with a clearance 242. Female threads are formed on an inner peripheral surface 25 of the mount hole 24. Male threads are formed on an outer peripheral surface 103 of the body 102. The female threads of the mount hole 24 and the male threads of the body 102 are screwed to each other, so that the relief valve 100 is mounted to the mount hole 24. A gasket 108 seals between the relief valve 100 and the mount hole 24 on the side of the discharge passage 250 with respect to the screwed part between the mount hole 24 and the body 102.

**[0045]** A fuel passage 252 communicated with a suction chamber 210 is formed in the body 102. The spring 106 biases the guide 105 and the ball 104 in the direction, in which the ball is seated on the valve seat member 107. Communication between the discharge passage 250 and the fuel passage 252 is interrupted when the ball 104 is seated on the valve seat member 107. The ball 104 is spaced from the valve seat member 107 against the bias of the spring 106 when fuel pressure downstream of the delivery valve 80 becomes equal to or greater than predetermined pressure. In this state, fuel in the discharge passage 250 flows into the suction chamber 210 through the fuel passage 252.

**[0046]** The valve seat member 107 is mounted to an inner peripheral wall of an end of the body 102. A fuel passage 254 is formed to extend axially through the valve seat member 107 to communicate with the discharge passage 250. A communication passage 256 is formed upstream of the location, in which the ball 104 is seated on the valve seat member 107. That is, the communication passage 256 is formed on the side on the discharge passage 250 to extend through the sidewall of the valve seat member 107 to communicate with the fuel passage 254. Further, an annular passage 258 is formed on an outer peripheral sidewall of the valve seat member 107 to communicate with the communication passage 256. A communication passage 260 is formed to extend through the sidewall of the body 102 in a manner to communicate with the annular passage 258.

**[0047]** The mount hole 24 and the body 102, which are screwed to each other, form a small clearance 262 therebetween. Specifically, an outer peripheral surface 103 of the body 102 and an inner peripheral surface 25 of the mount hole 24 form the small clearance 262 therebetween. The small clearance 262 extends from the screwed part between the mount hole 24 and the body 102 to the gasket 108 through the location, in which the communication passage 260 is formed.

**[0048]** The clearance 262 communicates with the communication passage 260, thereby communicating with the fuel passage 232 downstream of the valve seat member 87 of the delivery valve 80 through the discharge passage 250 and the clearance 242 formed on the side of the delivery valve 80. In addition, a slight clearance is present in the screwed part, in which the mount hole 24 and the body 102 are screwed to each other, and the clearance 262 communicates with the suction chamber 210 through the slight clearance in the screwed part between the mount hole 24 and the body 102. Accordingly, fuel downstream of the delivery valve 80 returns into the suction chamber 210 through the communication passage 240, the clearance 242, the discharge passage 250, the fuel passage 254, the communication passage 256, the annular passage 258, the communication passage 260, the clearance 262, and the screwed part, in which the mount hole 24 and the body 102 are screwed to each other. According to the second embodiment, the communication passage 240, the discharge passage 250, the fuel passage 254, the communication passage 256, the annular passage 258, and the communication passage 260 construct a return passage.

**[0049]** According to the second embodiment described above, fuel downstream of the delivery valve 80 passes through the small clearances 242, 262 in two locations, thereby returning into the suction chamber 210, so that an amount of fuel returning into the suction chamber 210 can be further reduced.

(Third Embodiment)

**[0050]** As follows, a high-pressure fuel pump 110 in the third embodiment is described in reference to FIGS. 7 to 10. FIG. 7 is the view taken along the line VII-VII in FIG. 8.

**[0051]** With the high-pressure fuel pump 110 in the third embodiment, small clearances 272, 284 are formed between outer peripheral surfaces 125, 135 of valve seat members 124, 134 of each of a delivery valve 120 and a relief valve 130 and inner peripheral surfaces 23, 25 of mount holes 22, 24. The delivery valve 120 and the relief valve 130 serve as functional components of the high-pressure fuel pump 110. The delivery valve 120 and the relief valve 130 are mounted to the inner peripheral surfaces 23, 25 of mount holes 22, 24.

**[0052]** Specifically, as shown in FIG. 9, the valve seat member 124 of the delivery valve 120 is fitted onto an outside of an end of a body 122 on the side of a discharge passage 230 to be coaxial with the body 122. The delivery valve 120 defines a fuel outlet of the high-pressure fuel pump 110. The clearance 272 formed between the outer peripheral surface 125 of the valve seat member 124 and the inner peripheral surface 23 of the mount hole 22 is substantially the same with respect to the circumferential direction. A communication passage 270 extends through the sidewall of the body 122 between the screwed part, in which the body 122 and the mount hole 22 are screwed to each other, and the gasket 88. The communication passage 270 communicates with a fuel passage 232 downstream of the valve seat member 124 and the clearance 272, so that an inlet of a return passage is provided in the delivery valve 120.

**[0053]** The relief valve 130 restricts abnormal rise in fuel pressure on the downstream side of the high-pressure fuel pump 110. As shown in FIG. 10, a body 132 and a valve seat member 134 of the relief valve 130 abut at end surfaces thereof against each other. The body 132 is screwed to the mount hole 24, so that the valve seat member 134 is pushed against the bottom of the mount hole 24.

**[0054]** The body 132 is formed with the fuel passage 252, which communicates with the suction chamber 210. The spring 106 biases the guide 105 and the ball 104 in the direction, in which the ball 104 is seated on the valve seat member 134. When the ball 104 is seated on the valve seat member 134, communication between the discharge passage 250 and the fuel passage 252 is interrupted. When fuel pressure downstream of the delivery valve 120 attains predetermined pressure or higher, the ball 104 is spaced from the valve seat member 134 against the bias of the spring 106, so that fuel in the discharge passage 250 is discharged into the suction chamber 210 through the fuel passage 252.

**[0055]** The valve seat member 134 is formed with a fuel passage 280, which extends axially therethrough to be communicated with the discharge passage 250. A communication passage 282 is formed upstream of the location, in which the ball 104 is seated on the valve seat member 134. That is, the communication passage 282 is formed on the side of the discharge passage 250 to extend through the sidewall of the valve seat member 134 to be communicated with the fuel passage 280. The communication passage 282 communicates with the clearance 284.

**[0056]** The clearance 284 communicates with the communication passage 282, thereby communicating with the downstream side of the valve seat member 124 of the delivery valve 120 through the discharge passage 250 and the clearance 272 formed on the delivery valve 120. In addition, a slight clearance is present in the screwed part, in which the mount hole 24 and the body 132 are screwed to each other. The clearance 284 communicates with the suction chamber 210 through this clearance in this screwed part between the mount hole 24 and the body 132. Accordingly, fuel downstream of the delivery valve 120 returns to the suction chamber 210 through the communication passage 270, the clearance 272, the discharge passage 250, the fuel passage 280, the communication passage 282, the clearance 284, and the screwed part, in which the mount hole 24 and the body 132 are screwed to each other. According to the third embodiment, the communication passage 270, the discharge passage 250, the fuel passage 280, and the communication passage 282 construct a return passage.

**[0057]** According to the third embodiment, fuel downstream of the delivery valve 120 returns through two locations such as the clearances 272, 284, similarly to the second embodiment. Therefore, an amount of fuel returning to the suction chamber 210 can be reduced.

**[0058]** In addition, the valve seat members 124, 134 are generally formed of a material having high hardness as compared with the bodies 122, 132, and the like, in order to reduce wear of seat portions. Therefore, machining work such as grinding work can be made in the valve seat members 124, 134 to define the outer diameter thereof with high accuracy. Accordingly, the clearances 272, 284 formed between the valve seat members 124, 134 and the inner peripheral surfaces 23, 25 of the mount holes 22, 24 can be set to be further small. Thereby, an amount of fuel returning to the suction chamber 210 can be further reduced.

(Fourth Embodiment)

**[0059]** As shown in FIG. 11, a fuel supply system according to a fourth embodiment includes a high-pressure fuel pump 140. With this high-pressure fuel pump 140, fuel leaking from the clearance 242 formed between the mount hole 22 and the delivery valve 80 passes outside the high-pressure fuel pump 140 to return into the fuel pipe 4 on the downstream side. Fuel is supplied from the fuel pump 1 into the high-pressure fuel pump 140 through the fuel pipe 4 on the downstream side.

(Fifth Embodiment)

**[0060]** As shown in FIG. 12, with a high-pressure fuel pump 150 in the fifth embodiment, a body 162 of a delivery valve 160 and the cylinder 12 are formed integral with each other. The delivery valve 160 defines a fuel outlet. A ball 164 and a spring 165 are received in the body 162. When fuel pressure in the compression chamber 220 attains predetermined pressure or higher, the ball 164 lifts against the bias of the spring 165, so that high-pressure fuel in the compression chamber 220 passes through the discharge passage 230 to be discharged from the delivery valve 160.

**[0061]** A communication passage 290 is formed in the cylinder 12. A slide clearance 292 is formed in a sliding part, in which the sliding portion 14 and the plunger 40 slide on each other. The communication passage 290 communicates the slide clearance 292 with the fuel passage 232, which is in the downstream of the ball 164 of the delivery valve 160. According to the fifth embodiment, the plunger 40 corresponds to one of the functional components. The sliding portion 14 of the cylinder 12 corresponds to a mount hole, to which the plunger 40 is mounted.

**[0062]** A low-pressure chamber 294 is formed between the sliding part, in which the plunger 40 and the sliding portion 14 slide on each other, and the oil seal 48. The low-pressure chamber 294 communicates with the suction chamber 210 through a discharge passage 296. Fuel in the fuel passage 232 downstream of the ball 164 passes from the fuel passage 232 into the low-pressure chamber 294 through the slide clearance 292. That is, fuel upstream of the fuel injection valves passes from the fuel passage 232 through the slide clearance 292 to leak into the low-pressure chamber 294, and passes through the discharge passage 296 to be returned into the suction chamber 210. In this manner, fuel downstream of the delivery valve 160 passes through the slide clearance 292 to return into the low-pressure side, so that fuel pressure downstream of the delivery valve 160 decreases, and fuel pressure upstream of the fuel injection valves also decreases when the fuel injection valves stop. According to the fifth embodiment, the communication passage 290, the low-pressure chamber 294, and the discharge passage 296 construct a return passage.

**[0063]** According to the fifth embodiment, the plunger 40 serves as one of the functional components. Fuel downstream of the delivery valve 160 returns to the suction chamber 210 of the high-pressure fuel pump 150 through the slide clearance 292 formed between the sliding portion 14 and the plunger 40. The sliding portion 14 of the cylinder 12 serves as the mount hole for receiving the plunger 40. Thus, a clearance need not be additionally formed between the plunger 40 and the sliding portion 14 to introduce return fuel downstream of the delivery valve 160 into the low-pressure side. Accordingly, machining work of the high-pressure fuel pump 150 can be reduced.

**[0064]** In addition, machining works are made to highly accurately define both the inner diameter of the sliding portion 14 and the outer diameter of the plunger 40 in order to restrict seizure of the sliding portion 14 with the plunger 40 and to restrict leakage of fuel from the compression chamber 220 through the slide clearance 292. Consequently, the slide clearance 292 is set to be small, so that an amount of fuel passing through the slide clearance 292 to return into the suction chamber 210 can be reduced.

**[0065]** Thereby, the high-pressure fuel pump 150 can be restricted from increasing in discharge capacity in order to make up for a flow rate of fuel returning to the low-pressure side through the slide clearance 292.

**[0066]** In FIG. 12, the length L depicts the length of the sealing part between the communication passage 290 and the low-pressure chamber 294. This sealing part is determined corresponding to the location, in which the communication passage 290 and the slide clearance 292 are communicated with each other. In this structure of the fifth embodiment, the slide clearance 292, a passage diameter d of the communication passage 290, and the length L of the sealing part can be adjusted, so that pressure reduction in fuel downstream of the delivery valve 160 can be desirably set. That is, pressure reduction in fuel upstream of the fuel injection valves 7 can be desirably set by adjusting the slide clearance 292, the passage diameter d, and the length L.

(Sixth Embodiment)

**[0067]** As shown in FIG. 13, with a high-pressure fuel pump 170 in the sixth embodiment, the communication passage 290 provides communication between the clearance 242, which is formed between the delivery valve 80 and the mount hole 22, and the slide clearance 292. Accordingly, fuel downstream of the delivery valve 80 passes through the clearance 242, the communication passage 290, the slide clearance 292, the low-pressure chamber 294, and the discharge passage 296 to return into the suction chamber 210 on the low-pressure side. According to the sixth embodiment, fuel downstream of the delivery valve 80 returns to the suction chamber 210 through the clearance 242 and the slide clearance 292 in two locations, so that it is possible to further reduce an amount of fuel returning to the suction chamber 210.

(Seventh and Eighth Embodiments)

**[0068]** As shown in FIG. 14, with a high-pressure fuel pump 180 according to the seventh embodiment, an annular groove 185 is formed on the outer peripheral surface of a sliding portion 184 of a plunger 182. The plunger 182 serves as one of the functional components, which slides on the sliding portion 14 of the cylinder 12. An annular fuel reservoir 298 is formed between a periphery of the groove 185 and the sliding portion 14. The communication passage 290 provides communication between the fuel passage 232 downstream of the delivery valve 160 and the fuel reservoir 298. Fuel downstream of the delivery valve 160 passes from the fuel passage 232 through the communication passage 290, the fuel reservoir 298, a slide clearance 292, the low-pressure chamber 294, and the discharge passage 296 to return into the suction chamber 210. According to the seventh embodiment, the communication passage 290, the fuel reservoir 298, the low-pressure chamber 294, and the discharge passage 296 construct a return passage.

**[0069]** In the seventh embodiment, fuel downstream of the delivery valve 160 is once accumulated in the annular fuel reservoir 298 from the communication passage 290 and then passes through the slide clearance 292. Thereby, high-pressure fuel in the annular fuel reservoir 298 applies fuel pressure uniformly on the entire periphery of the sliding portion 184 of the plunger 182 even when high-pressure fuel flows into the annular fuel reservoir 298 from the communication passage 290 in one circumferential direction. Accordingly, the sliding portion 184 of the plunger 182 can be restricted from being eccentric with respect to the sliding portion 14 of the cylinder 12. Therefore, the sliding portion 184 of the plunger 182 can be restricted from sliding on one side in the circumferential direction. Thereby, plating or coating, which is applied to the plunger 182 for restriction of seizure of the sliding portion 14 with the sliding portion 184, can be protected from abrasion, so that manufacturing cost of the plunger 182 can be reduced.

**[0070]** Furthermore, the sliding portion 14 of the cylinder 12 can be lubricated with the return fuel accumulated in the annular fuel reservoir 298, while the plunger 182 slides on the sliding portion 14. Therefore, the sliding portion 184 of the plunger 182 can be further restricted from causing seizure with the plunger 12.

**[0071]** As shown in FIG. 15, with a high-pressure fuel pump 190 according to the eighth embodiment, the communication passage 290 and the fuel reservoir 298 are communicated with each other through the slide clearance 292 therebetween. Accordingly, fuel downstream of the delivery valve 160 passes from the fuel passage 232 to return into the suction chamber 210 through the communication passage 290, the slide clearance 292, the fuel reservoir 298, the slide clearance 292, the low-pressure chamber 294, and the discharge passage 296.

**[0072]** The sliding portion 14 of the cylinder 12 can be lubricated with the return fuel accumulated in the annular fuel reservoir 298, thereby being further restricted from causing seizure with the plunger 12, similarly to the eighth embodiment.

**[0073]** Summarizing the above embodiments, the fuel supply system has the fuel pump that includes the pump housing, the plunger, the delivery valve, and at least one fluid component. The pump housing has the compression chamber and at least one mount hole. The plunger is movable in the pump housing. The plunger is adapted to pressurize fuel in the compression chamber. The delivery valve communicates the compression chamber with the downstream of the delivery valve when pressure in the compression chamber is equal to or greater than the threshold, i.e., predetermined pressure. The at least one fluid component is adapted to communicating the upstream of the compression chamber with the downstream of the compression chamber.

**[0074]** At least one of the plunger, the delivery valve, and the at least one of fluid component is provided to the at least one mount hole of the pump housing. The at least one of the plunger, the delivery valve, and the at least one of fluid component defines at least one clearance with respect to the at least one mount hole. The at least one clearance communicates the downstream of the delivery valve with the upstream of the compression chamber at least in the condition where fuel pressure in the compression chamber is less than the threshold.

**[0075]** The at least one fluid component may include at least one of the relief valve and the metering valve. The relief valve is adapted to restrict pressure in the downstream of the delivery valve from rising. The metering valve 60 is arranged between the upstream of the compression chamber and the compression chamber. The metering valve is adapted to communicating and blocking the upstream of the compression chamber with the compression chamber.

(Other Embodiments)

**[0076]** According to the above embodiments, fuel downstream of the delivery valve returns into the low-pressure side through at least one of the small clearances. This at least one of the small clearances is formed around at least one of the delivery valve, the relief valve, and the plunger. However, fuel may be returned through a clearance formed between another component, which serves as one of the functional components of a high-pressure fuel pump, and a mount hole. This mount hole may define a sliding part of one of the functional components. In addition, a clearance, through which fuel passes, formed between that functional component and a mount hole is not limited to one or two locations. Clearances may be provided in at least three locations for introducing fuel.

**[0077]** In addition, according to the above embodiments, the cylinder supports the plunger to permit reciprocation thereof, and the at least one of the functional components such as the piping joint 50, the delivery valve, the relief valve are mounted directly to the cylinder. However, the cylinder supporting the plunger and the housing body, to which the functional components are mounted, may be separate from each other.

**[0078]** Furthermore, the respective embodiments have been described with respect to an example, in which the high-pressure fuel pump is applied to a high-pressure fuel pump of a direct injection type gasoline supply system. However, the high-pressure fuel pump is not limited to those in the above embodiments, and may be applied to a fuel supply system for diesel engines, for example.

**[0079]** The above structures of the embodiments can be combined as appropriate. For example, the structures of the fuel reservoir described in the seventh and eighth embodiments may be combined with the structures of any one of the first to fourth embodiments.

**[0080]** Various modifications and alternations may be diversely made to the above embodiments without departing from the spirit of the present invention.

**[0081]** A delivery valve (80) is connected to a discharge passage (230), through which fuel in a compression chamber (220) is discharged. The delivery valve (80) is screwed to a mount hole (22) formed in the cylinder (12). A communication passage (240) is formed in a body (82) to extend through the sidewall between a screwed part, in which the mount hole (22) and the body (82) are screwed to each other, and a gasket (88). A small clearance (242) is formed between an inner peripheral surface (23) of the mount hole (22) and an outer peripheral surface (83) of the body (82). The communication passage (240) provides communication between a fuel passage (232) downstream of a valve seat member (87) and the clearance (242). The clearance (242) communicates with the suction chamber (210) through a return passage (240, 270, 290) formed in the cylinder (12).

## Claims

**1.** A fuel pump (10, 90, 110, 140, 150, 170, 180, 190) that supplies fuel to a delivery pipe (6), the fuel pump **characterized by** comprising:

a pump housing (12, 30) that has a compression chamber (220) and at least one mount hole (22, 24, 14);

a plunger (40) that is movable in the pump housing (12, 30), the plunger (40) being adapted to pressurizing fuel drawn into the compression chamber (220);

a delivery valve (80, 120, 160) that communicates the compression chamber (220) with the delivery pipe (6) when fuel pressure in the compression chamber (220) is equal to or greater than a threshold; and

at least one functional component (40, 60, 80, 120, 160, 100, 130) that is provided to the at least one mount hole (22, 24, 14) of the pump housing (12, 30),

wherein the at least one functional component (40, 60, 80, 120, 160, 100, 130) and the at least one mount hole (22, 24, 14) define at least one clearance (242, 262, 272, 284, 242, 292) therebetween, and fuel on a downstream side of the delivery valve (80, 120, 160) returns into a low-pressure side thereof through the at least one clearance (242, 262, 272, 284, 242, 292).

**2.** The fuel pump according to claim 1, wherein the at least one clearance (242, 262, 272, 284, 242, 292) includes a plurality of clearances (242, 262, 272, 284, 242, 292), and fuel on the downstream side of the delivery valve (80, 120, 160) passes through the plurality of clearances (242, 262, 272, 284, 242, 292) to return into the low-pressure side.

**3.** The fuel pump according to claim 1 or 2, wherein the delivery valve (80, 120, 160) has an inlet of a return passage (240, 270, 290), through which fuel on the downstream side of the delivery valve (80, 120, 160) returns to a low-pressure side thereof.

**4.** The fuel pump according to any one of claims 1 to 3, wherein the delivery valve (80, 120, 160) is one of the at least one functional component (40, 60, 80, 120, 160, 100, 130).

**5.** The fuel pump according to any one of claims 1 to 4, wherein the plunger (40) is one of the at least one functional component (40, 60, 80, 120, 160, 100, 130), and fuel on the downstream side of the delivery valve (80, 120, 160) returns to a low-pressure side thereof through one of the at least one clearance (242, 262, 272, 284, 242, 292) defined in a sliding part, in which the plunger (40) slides on the pump housing (12, 30).

**6.** The fuel pump according to any one of claims 1 to 5, wherein the at least one functional component (40, 60, 80, 120, 160, 100, 130) includes at least one of

a relief valve (100, 130) and a metering valve (60), the relief valve (100, 130) restricts fuel pressure on the downstream side of the delivery valve (80, 120, 160) from rising, and
the metering valve (60) is arranged between the upstream of the compression chamber (220) and the compression chamber (220), the metering valve (60) being adapted to communicating and blocking the upstream of the compression chamber (220) with the compression chamber (220).

**7.** The fuel pump according to any one of claims 1 to 6, wherein fuel passing through the at least one clearance (242, 262, 272, 284, 242, 292) returns into the pump housing (12, 30).

**8.** The fuel pump according to any one of claims 1 to 7, wherein the at least one mount hole (22, 24, 14) has an inner peripheral surface (23, 25), which is substantially circular in shape, and
the at least one functional component (40, 60, 80, 120, 160, 100, 130) has an outer peripheral surface (83, 103), which is substantially circular in shape.

**9.** The fuel pump according to any one of claims 1 to 8, wherein the at least one clearance (242, 262, 272, 284, 242, 292) communicates the downstream side of the delivery valve (80, 120, 160) with an upstream side of the compression chamber (220) at least in a condition where fuel pressure in the compression chamber (220) is less than the threshold.

**10.** A fuel supply system including a fuel pump (10, 90, 110, 140, 150, 170, 180, 190) **characterized by** comprising:

a pump housing (12, 30) that has a compression chamber (220) and at least one mount hole (22, 24, 14);
a plunger (40) that is movable in the pump housing (12, 30), the plunger (40) being adapted to pressurizing fuel in the compression chamber (220);
a delivery valve (80, 120, 160) that communicates the compression chamber (220) with a downstream of the delivery valve (80, 120, 160) when pressure in the compression chamber (220) is equal to or greater than a threshold; and
at least one fluid component (100, 130, 60) that is adapted to communicating an upstream of the compression chamber (220) with a downstream of the compression chamber (220),

wherein at least one of the plunger (40), the delivery valve (80, 120, 160), and the at least one of fluid component (100, 130, 60) is provided to the at least one mount hole (22, 24, 14) of the pump housing (12, 30),
the at least one of the plunger (40), the delivery valve (80, 120, 160), and the at least one of fluid component (100, 130, 60) defines at least one clearance (242, 262, 272, 284, 242, 292) with respect to the at least one mount hole (22, 24, 14), and
the at least one clearance (242, 262, 272, 284, 242, 292) communicates the downstream of the delivery valve (80, 120, 160) with the upstream of the compression chamber (220) at least in a condition where fuel pressure in the compression chamber (220) is less than the threshold.

**11.** The fuel supply system according to claim 10, wherein the at least one fluid component (100, 130, 60) includes at least one of a relief valve (100, 130) and a metering valve (60),
the relief valve (100, 130) is adapted to restricting pressure in the downstream of the delivery valve (80, 120, 160) from rising, and
the metering valve (60) is arranged between the upstream of the compression chamber (220) and the compression chamber (220), the metering valve (60) being adapted to communicating and blocking the upstream of the compression chamber (220) with the compression chamber (220).

**12.** The fuel supply system according to claim 10 or 11, wherein the at least one clearance (242, 262, 272, 284, 242, 292) includes a plurality of clearances (242, 262, 272, 284, 242, 292), and
the downstream of the delivery valve (80, 120, 160) communicates with the upstream of the compression chamber (220) through the plurality of clearances (242, 262, 272, 284, 242, 292).

**13.** The fuel supply system according to any one of claims 10 to 12, wherein the delivery valve (80, 120, 160) has an inlet of a return passage (240, 270, 290), through which the downstream of the delivery valve (80, 120, 160) communicates with the upstream of the compression chamber (220).

**14.** The fuel supply system according to any one of claims 10 to 13,
wherein the plunger (40) defines a sliding part, in which the plunger (40) slides through one of the at least one mount hole (22, 24, 14) of the pump housing (12, 30), and
the plunger (40) defines one of the at least one of the clearance (242, 262, 272, 284, 242, 292) with respect to the one of the at least one mount hole (22, 24, 14) in the sliding part.

**15.** The fuel supply system according to any one of claims 10 to 14, wherein the at least one clearance (242, 262, 272, 284, 242, 292) communicates with an inside of the pump housing (12, 30) upstream of the compression chamber (220).

**16.** The fuel supply system according to any one of claims 10 to 15,
wherein the at least one mount hole (22, 24, 14) has an inner peripheral surface (23, 25), which is substantially circular in shape, and
the at least one functional component (40, 60, 80, 120, 160, 100, 130) has an outer peripheral surface (83, 103), which is substantially circular in shape.

**17.** A fuel supply system including a fuel pump (10, 90, 110, 140, 150, 170, 180, 190) **characterized by** comprising:

a pump housing (12, 30) that has a compression chamber (220) and a mount hole (22, 24, 14);
a plunger (40) that is movable in the pump housing (12, 30), the plunger (40) being adapted to pressurizing fuel in the compression chamber (220);
a delivery valve (80, 120, 160) that communicates the compression chamber (220) with a downstream of the delivery valve (80, 120, 160) when pressure in the compression chamber (220) is equal to or greater than a threshold; and

wherein the delivery valve (80, 120, 160) is provided to the mount hole (22, 24, 14) of the pump housing (12, 30),
the delivery valve (80, 120, 160) defines a clearance (242, 262, 272, 284, 242, 292) with respect to the mount hole (22, 24, 14), and
the clearance (242, 262, 272, 284, 242, 292) communicates the downstream of the delivery valve (80, 120, 160) with the upstream of the compression chamber (220) at least in a condition where fuel pressure in the compression chamber (220) is less than the threshold.

**18.** A fuel supply system including a fuel pump (10, 90, 110, 140, 150, 170, 180, 190) **characterized by** comprising:

a pump housing (12, 30) that has a compression chamber (220);
a plunger (40) that is movable in the pump housing (12, 30) to pressurize fuel in the compression chamber (220); and
a delivery valve (80, 120, 160) that communicates the compression chamber (220) with a downstream of the delivery valve (80, 120, 160) when pressure in the compression chamber (220) is equal to or greater than a threshold,

wherein the pump housing (12, 30) at least partially defines at least one clearance (242, 262, 272, 284, 242, 292) that communicates the downstream of the delivery valve (80, 120, 160) with an upstream of the compression chamber (220) at least in a condition where fuel pressure in the compression chamber (220) is less than the threshold.

FIG. 1

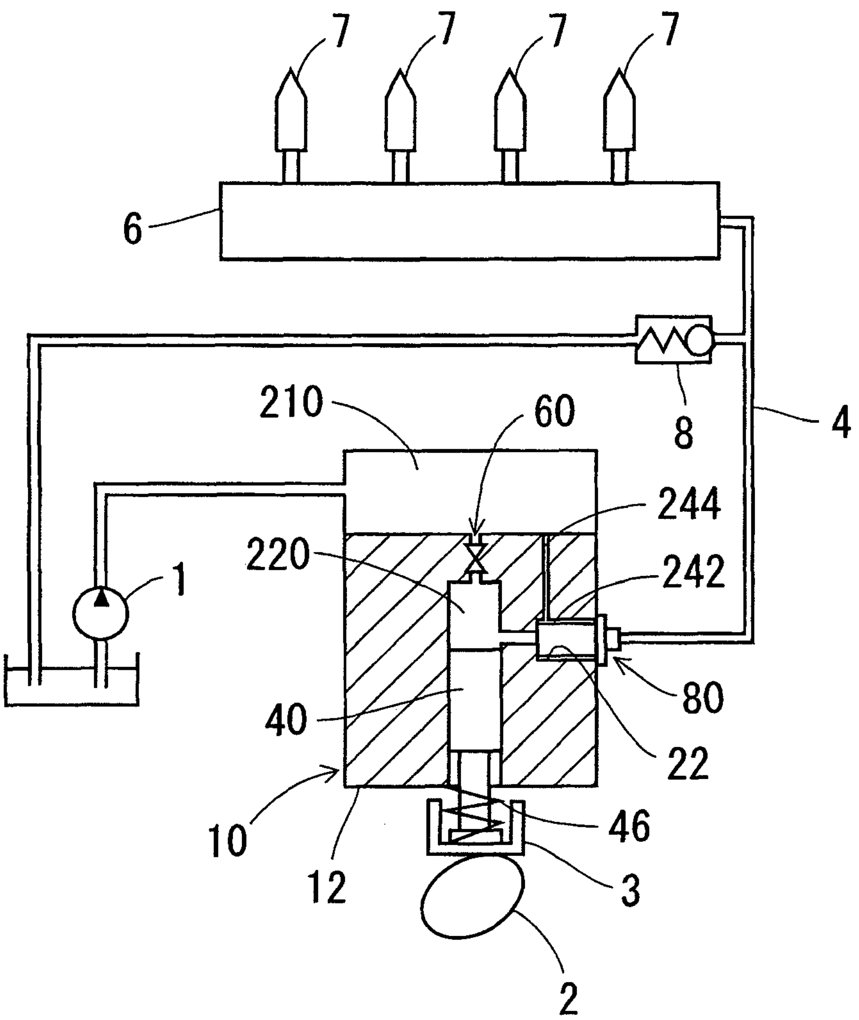


FIG. 2A

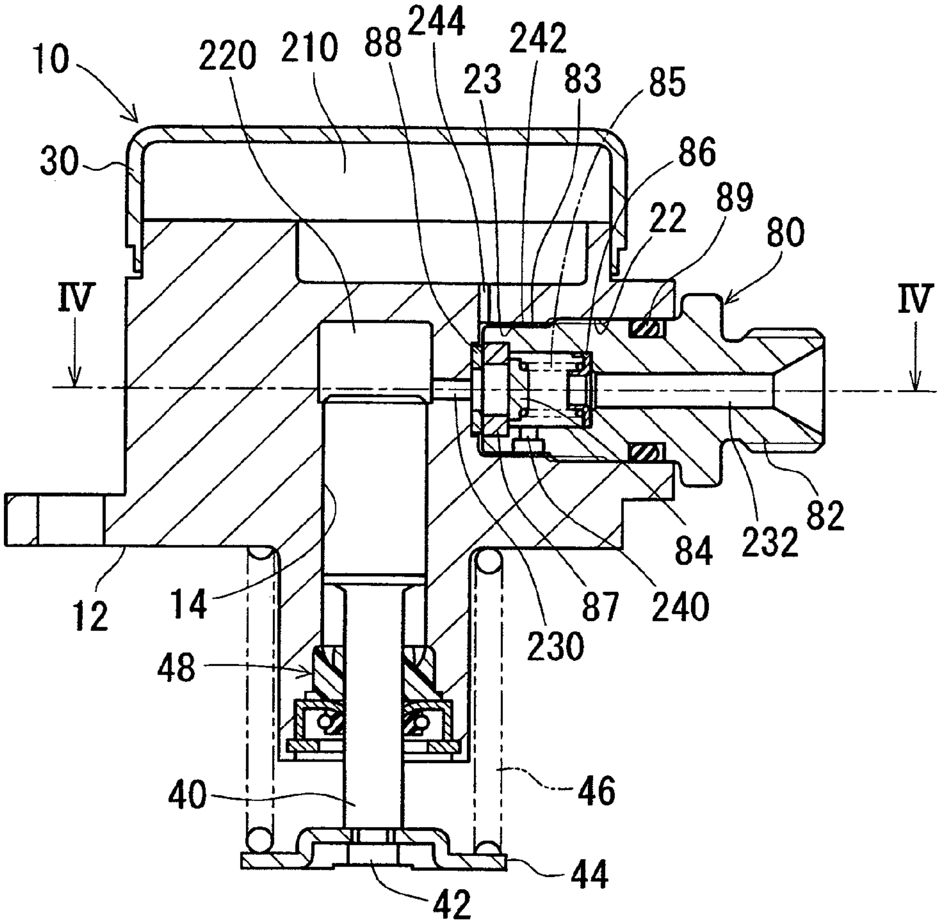
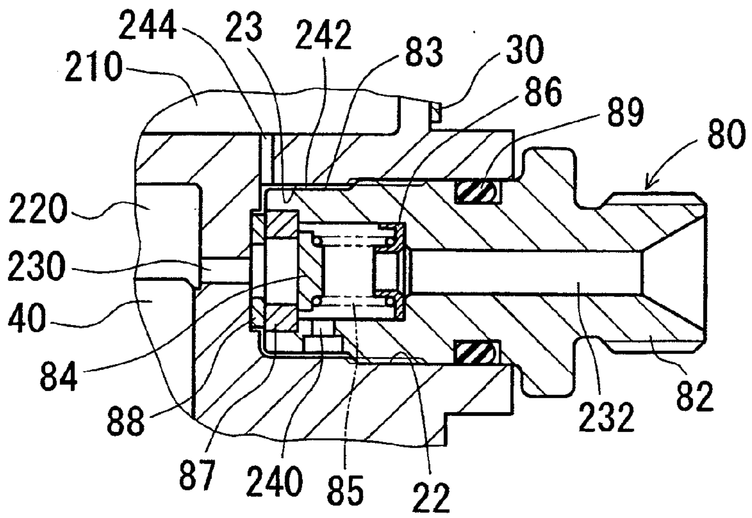

10
220
210
88
244
23
242
83
85
30
86
22
89
80
IV
IV
82
232
84
240
87
230
12
14
48
40
46
44
42

FIG. 2B


244
23
242
83
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86
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80
220
230
40
84
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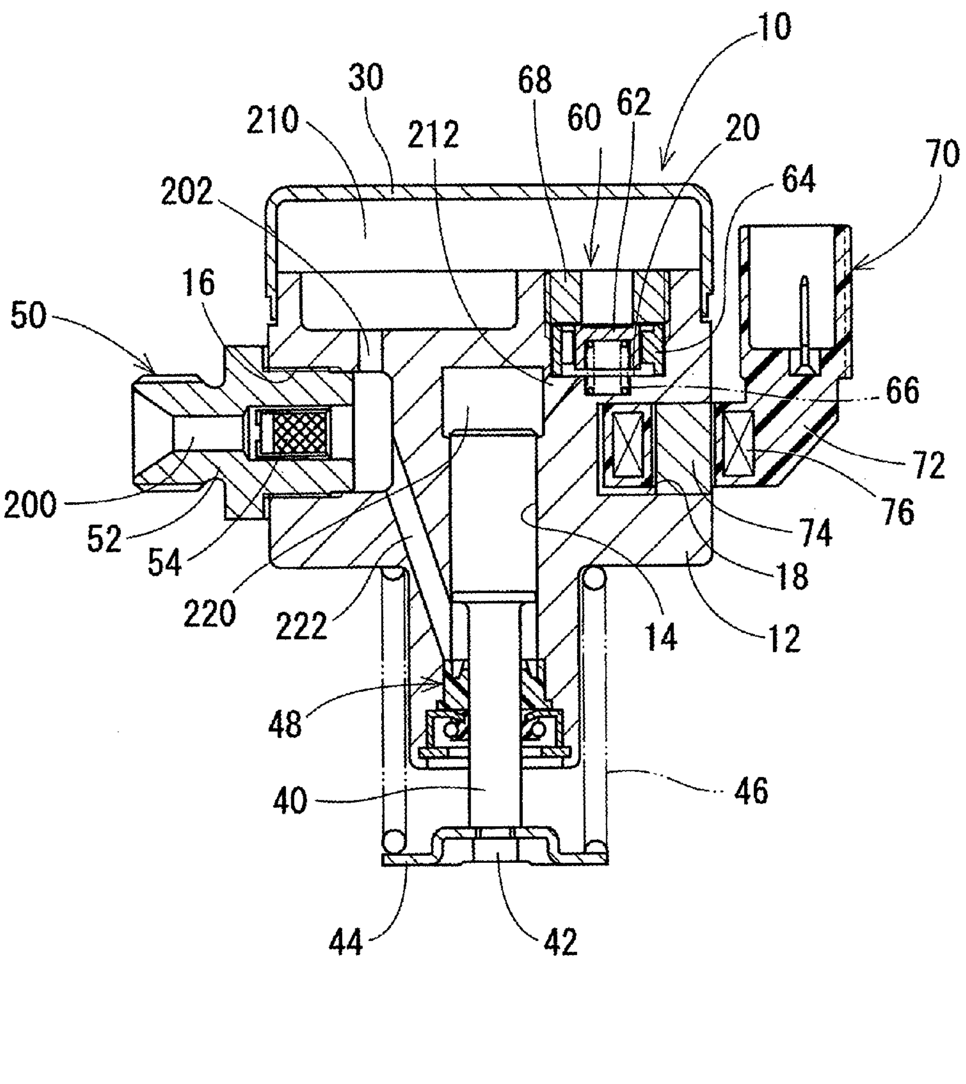
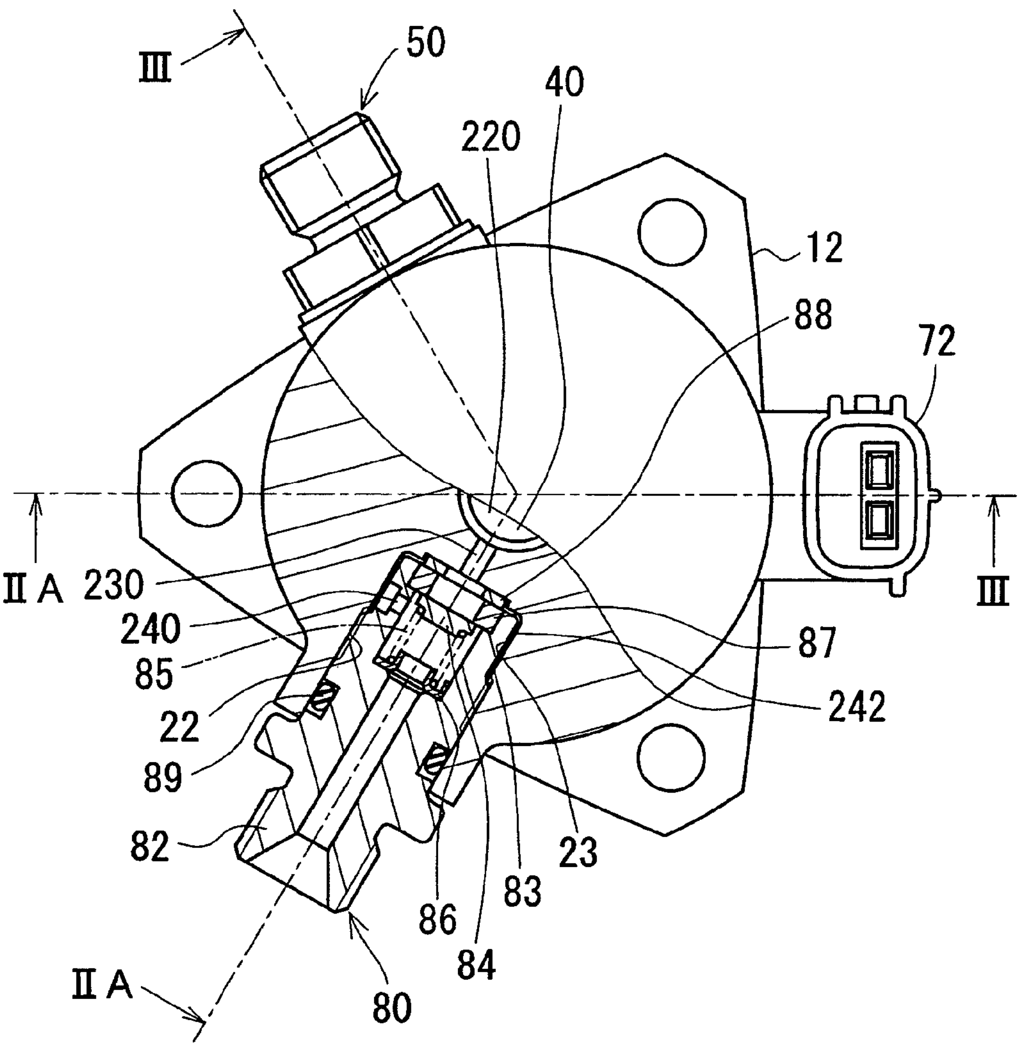
22
232
82

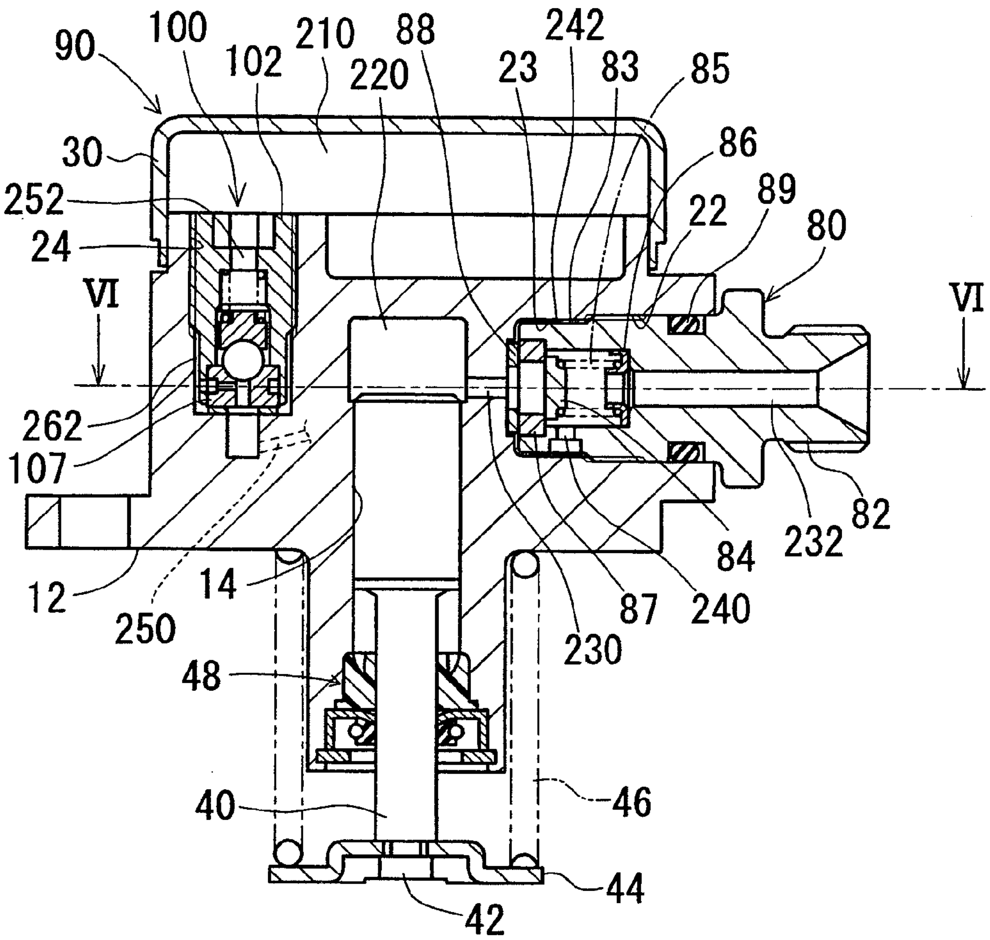
# FIG. 3


10
30
68
60
62
20
70
210
212
64
202
16
50
66
72
76
74
200
52
54
18
220
222
14
12
48
46
40
44
42

# FIG. 4


III
50
40
220
12
88
72
II A
230
240
85
22
89
82
III
87
242
23
83
86
84
80
II A

# FIG. 5A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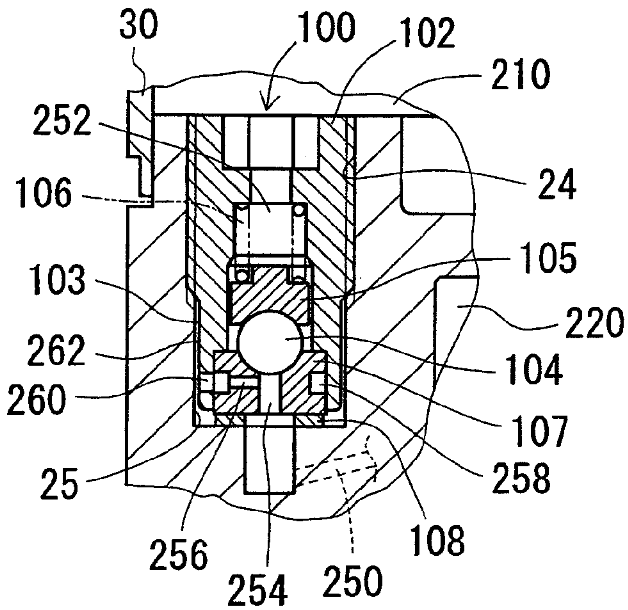
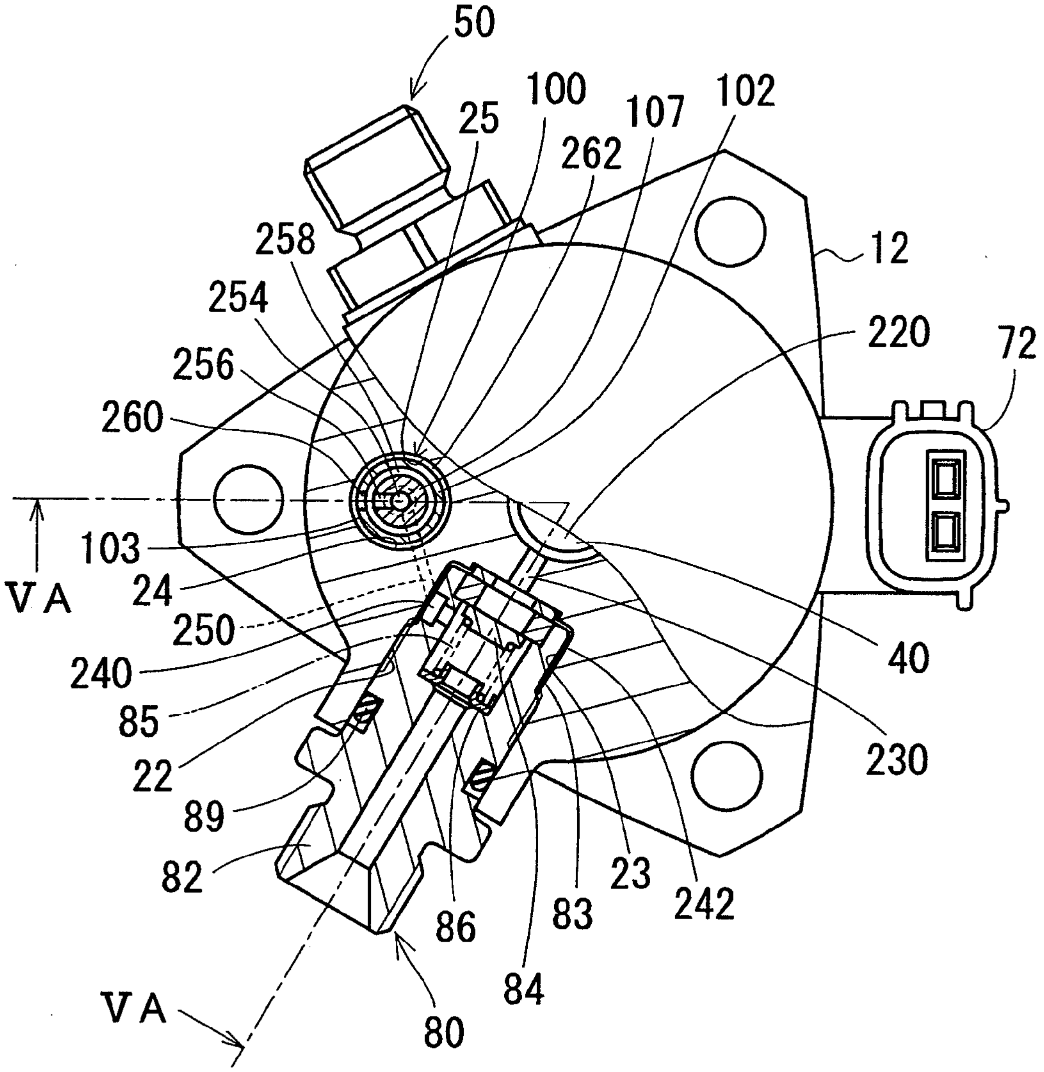
100
102
210
88
220
242
23
83
85
30
86
252
22
89
80
24
VI
VI
262
107
84
232
82
12
14
87
240
250
230
48
40
46
44
42

# FIG. 5B


30
100
102
210
252
106
24
103
105
220
262
104
260
107
25
258
108
256
254
250

# FIG. 6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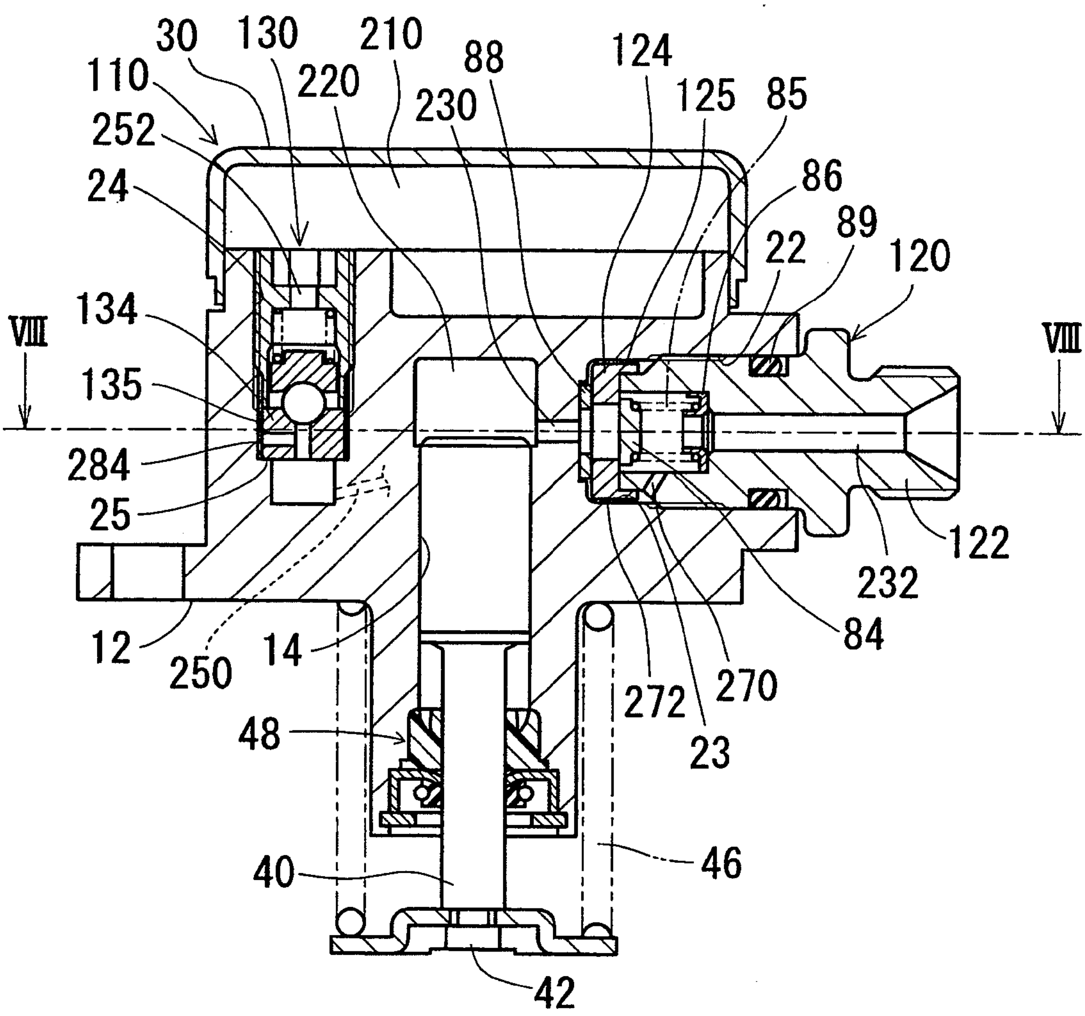
25
100
107
102
262
258
12
254
220
72
256
260
103
VA
24
250
240
40
85
230
22
89
82
23
242
86
83
84
VA
80

# FIG. 7


30
130
210
110
220
88
124
125
85
252
230
86
24
89
22
120
134
VIII
VIII
135
284
25
232
122
12
250
14
84
272
270
23
48
46
40
42

# FIG. 8

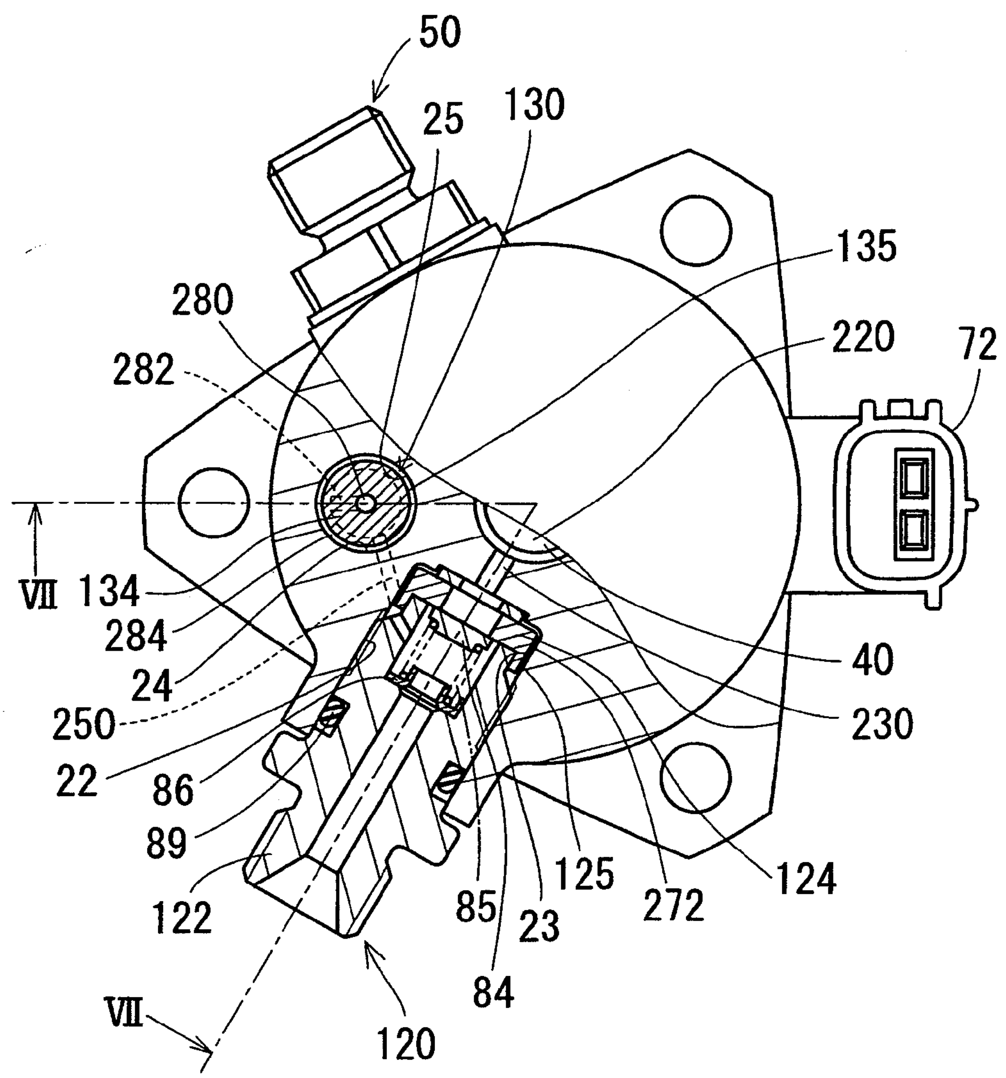
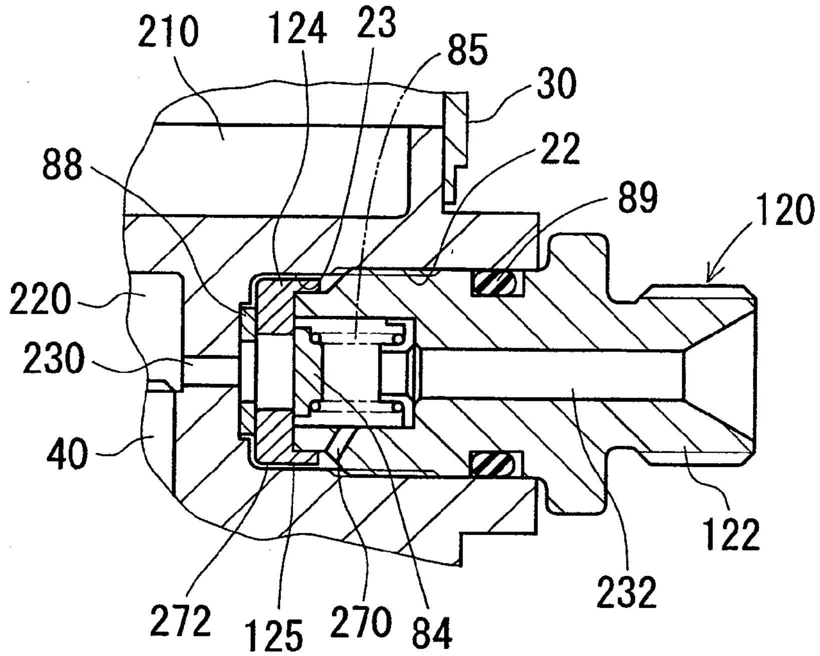

50
25
130
135
280
220
72
282
VII
134
284
24
250
22
86
89
122
40
230
124
125
272
85
23
84
120
VII

FIG. 9


210
124
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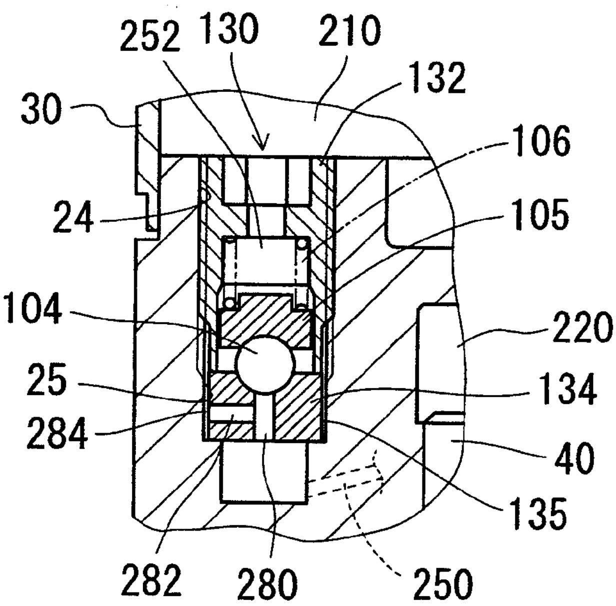
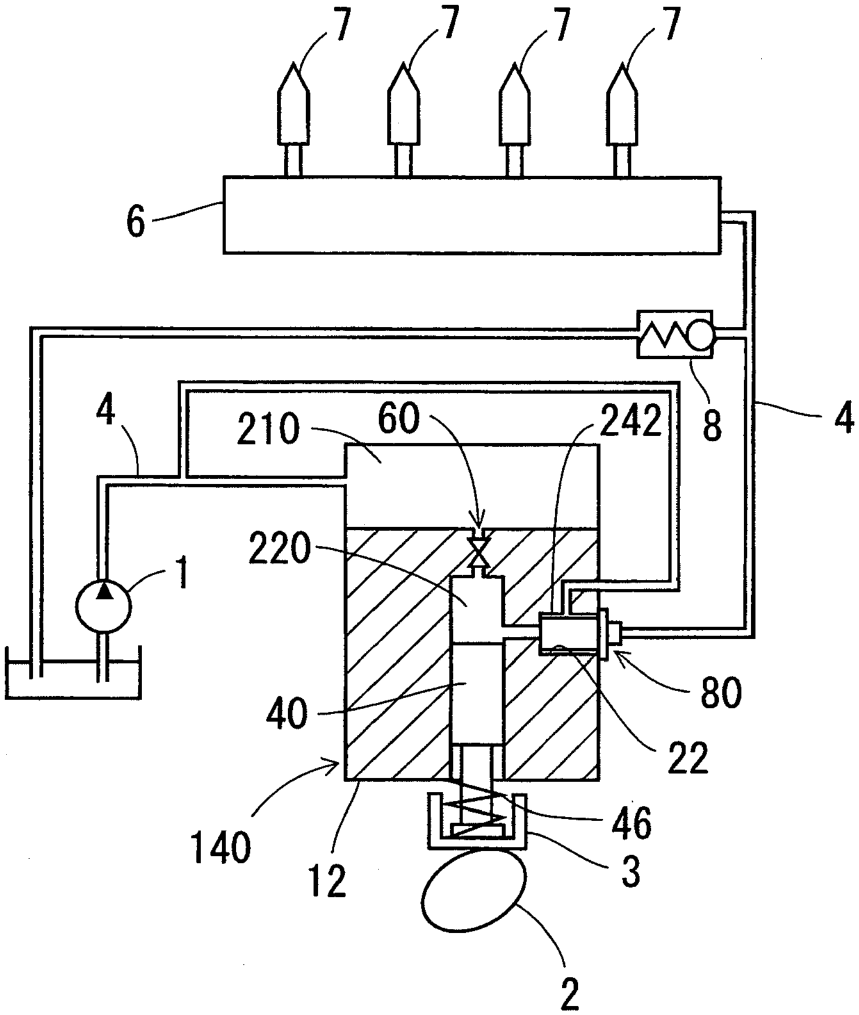
85
30
22
88
89
120
220
230
40
122
232
272
125
270
84

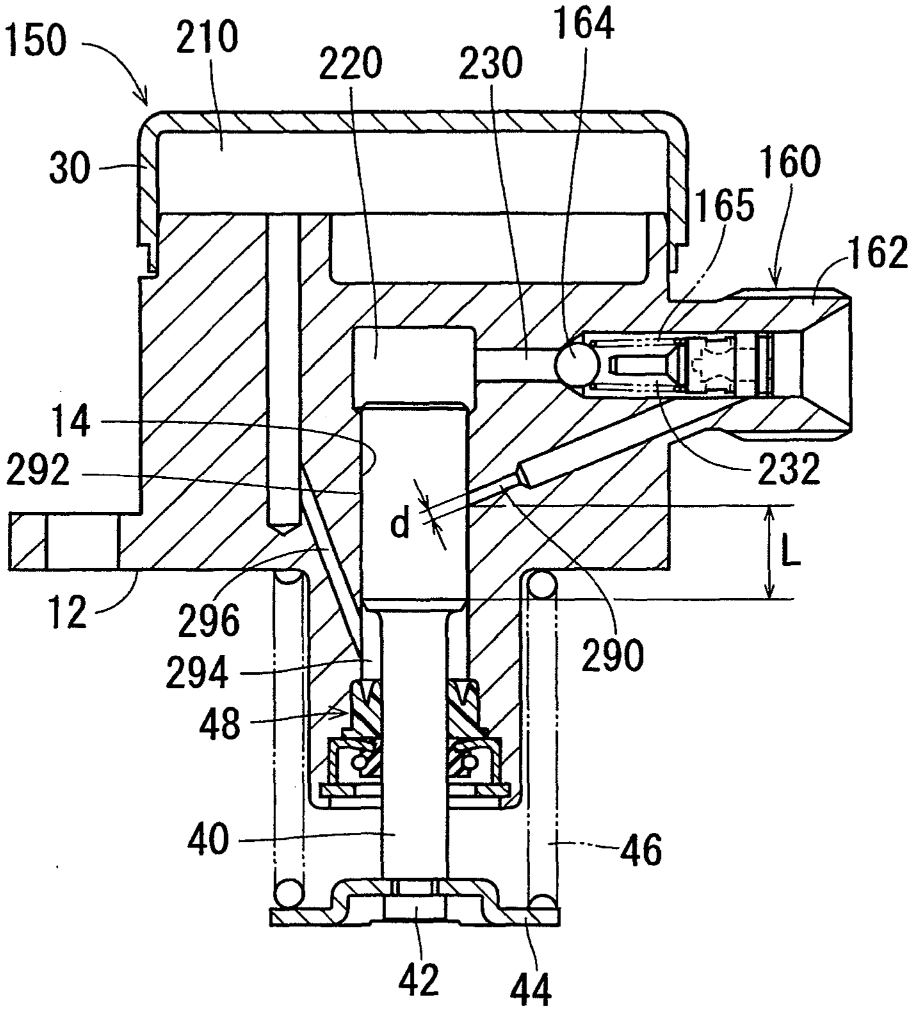
FIG. 10


252
130
210
132
30
106
24
105
104
220
25
134
284
40
135
282
280
250

# FIG. 11



# FIG. 12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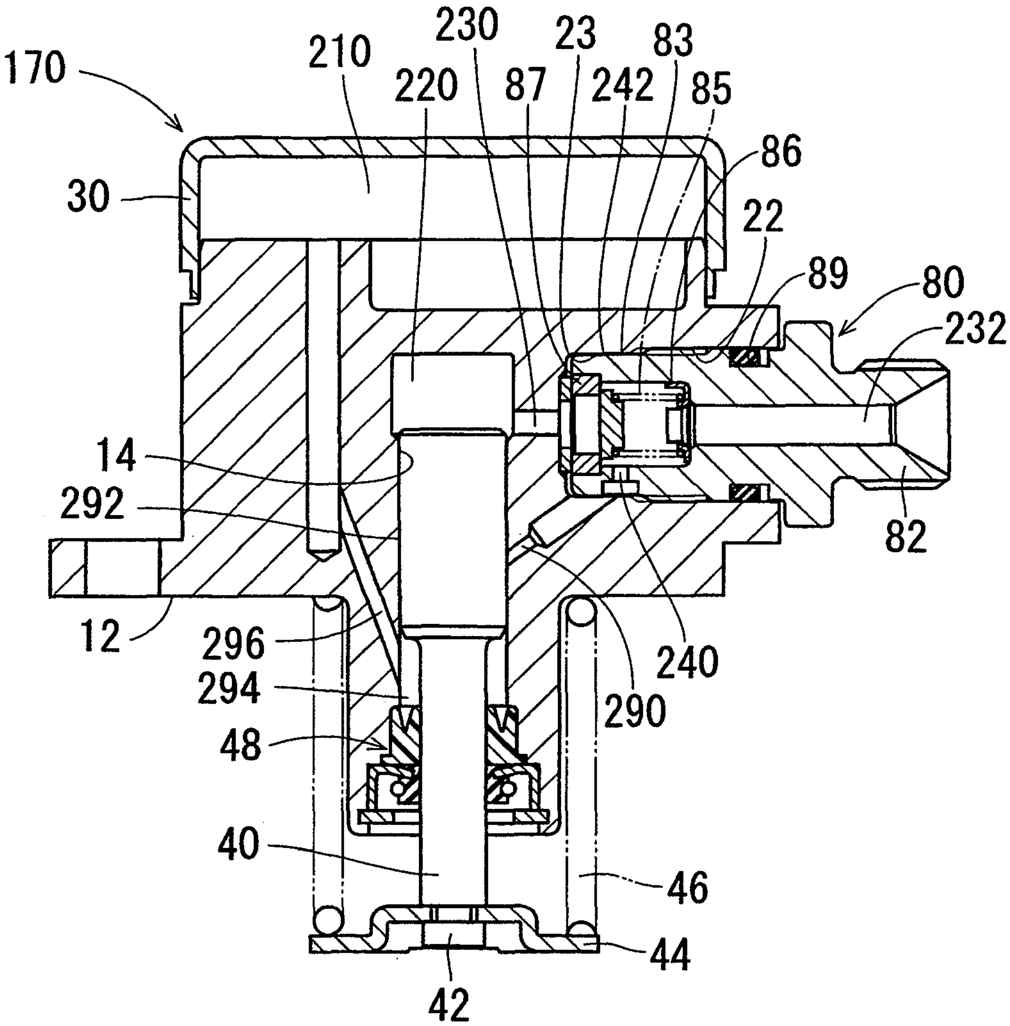
# FIG. 13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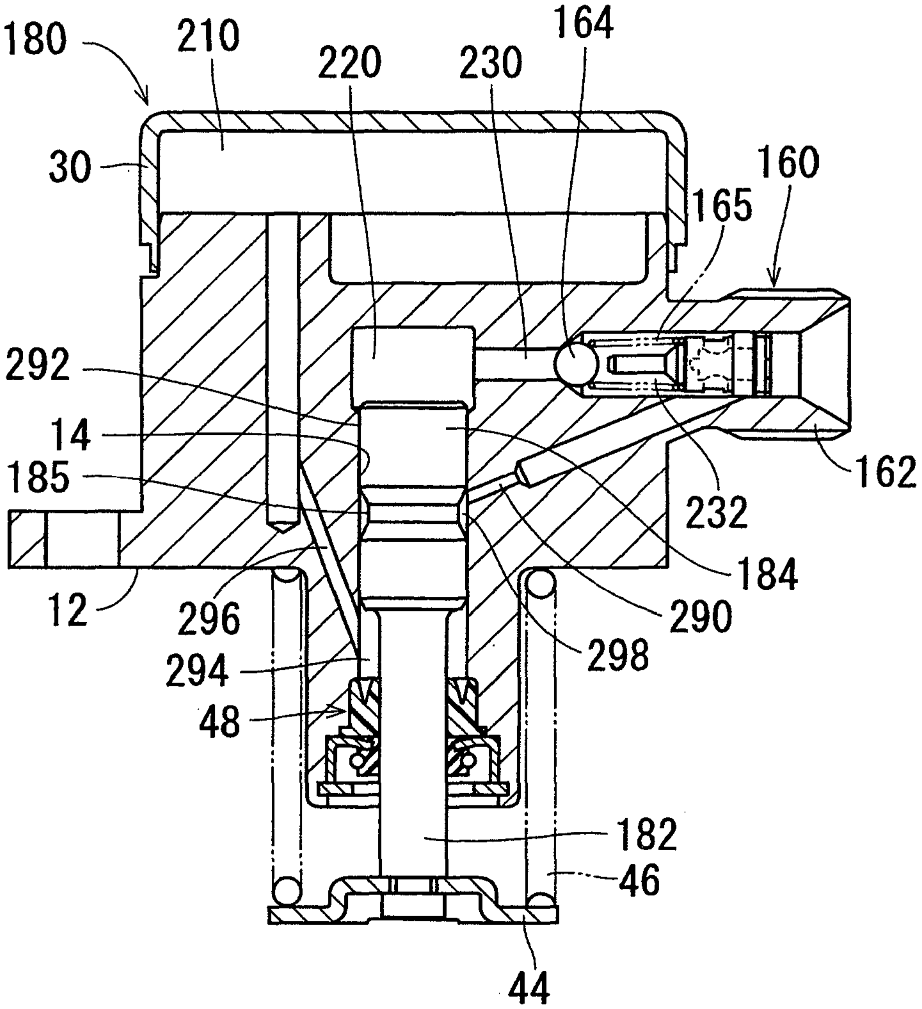
# FIG. 14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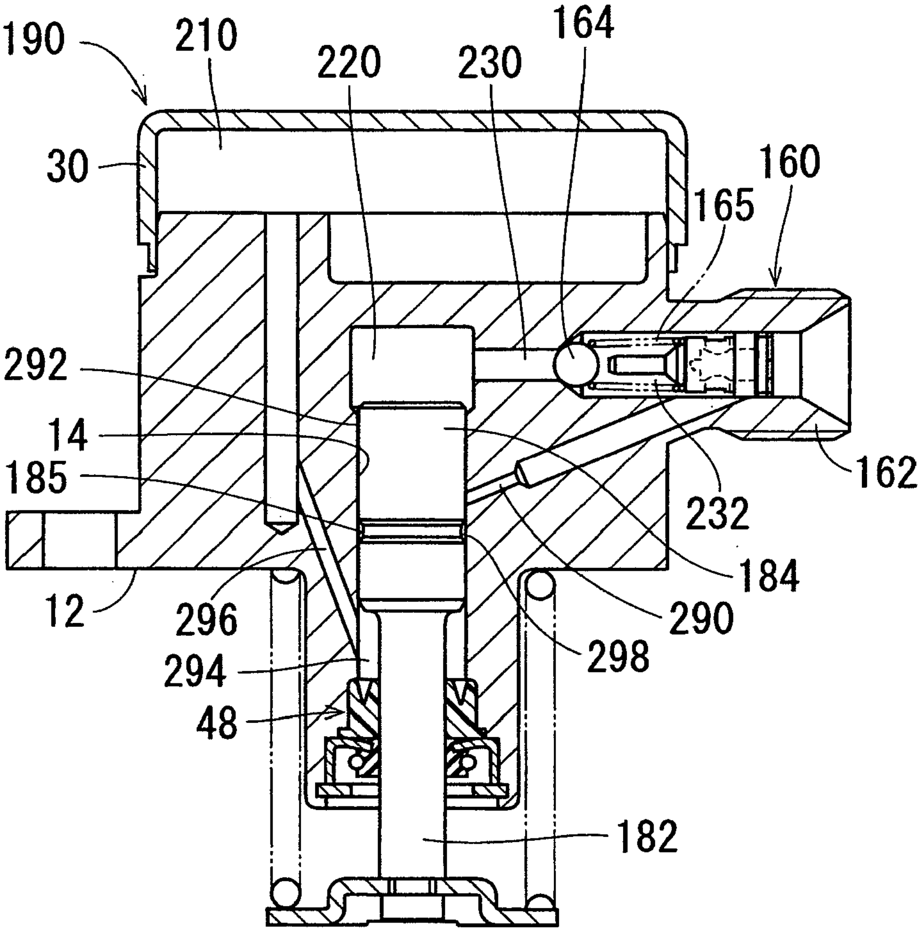
# FIG. 15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Application Number
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| The Hague | 24 August 2006 | Tortosa Masiá, A.A. |

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