

(19)



(11)

EP 3 088 722 A1

(12)

EUROPEAN PATENT APPLICATION

(43) Date of publication:

02.11.2016 Bulletin 2016/44

(51) Int Cl.:

F02M 37/00 (2006.01)

B01D 35/00 (2006.01)

F02M 55/00 (2006.01)

F02M 37/22 (2006.01)

B01D 35/18 (2006.01)

F02M 31/14 (2006.01)

(21) Application number: **16164218.6**

(22) Date of filing: **07.04.2016**

(84) Designated Contracting States:

AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR

Designated Extension States:

BA ME

Designated Validation States:

MA MD

(71) Applicant: **Toyota Jidosha Kabushiki Kaisha**
Toyota-shi, Aichi-ken, 471-8571 (JP)

(72) Inventor: **HIKICHI, Yuto**

Aichi-Ken, Aichi 471-8571 (JP)

(74) Representative: **D Young & Co LLP**

120 Holborn

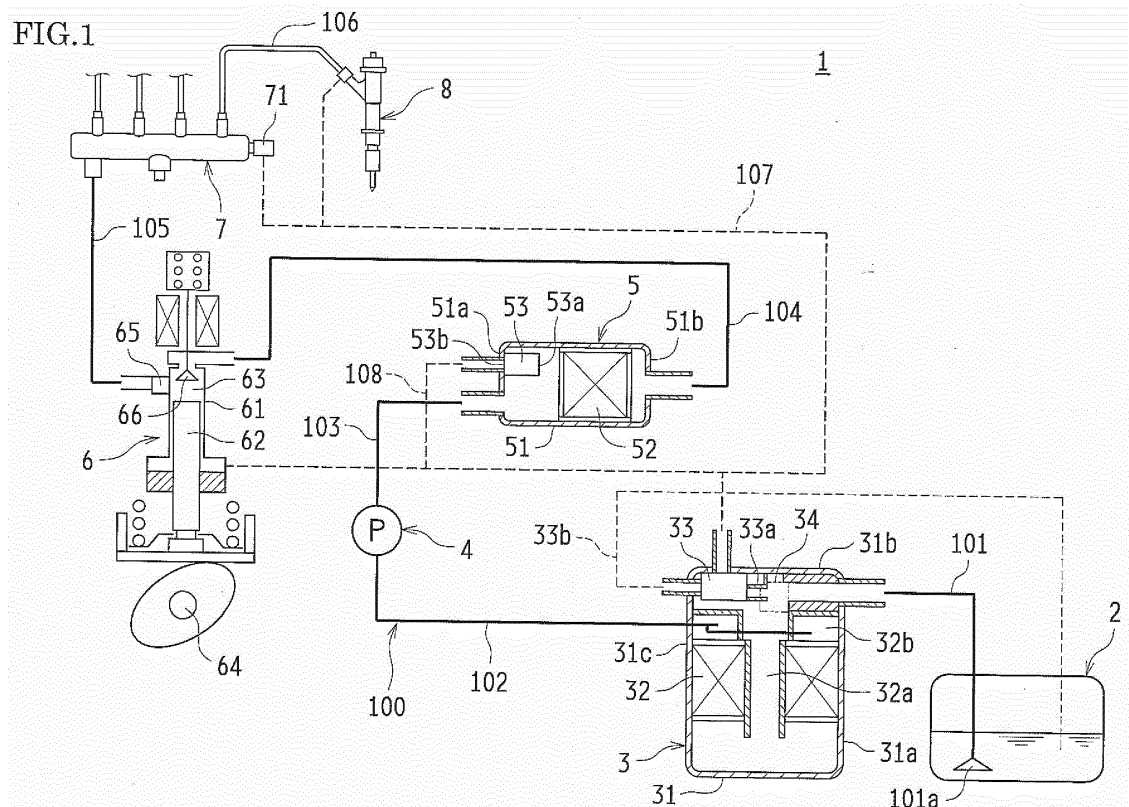
London EC1N 2DY (GB)

(30) Priority: **07.04.2015 JP 2015078189**

(54) FUEL SUPPLY DEVICE FOR INTERNAL COMBUSTION ENGINE

(57) A fuel supply device for an internal combustion engine is provided, which includes a plurality of fuel filters and is capable of reducing: the number of replacement parts; and clogging of filter elements by deposition of wax. A fuel supply path 100 for supplying fuel in a fuel tank 2 to injectors 8 includes: a first fuel filter 3 that is disposed upstream of a feed pump 4 and that has a first

filter element 32; and a second fuel filter 5 that is disposed downstream of the feed pump 4 and that has a second filter element 52. A fuel return pipe 108 and a fuel return pipe 107 are provided so that fuel discharged from the feed pump 4 is returned, via the second fuel filter 5, to a returned fuel heater 34 disposed upstream of the first filter element 32 in the first fuel filter 3.



EP 3 088 722 A1

Description

Technical Field

[0001] The present invention relates to a fuel supply device for an internal combustion engine that is mounted on a vehicle and the like.

Background Art

[0002] In some cases where fuel for an automotive engine and the like (specifically, for a diesel engine) is used under a low-temperature environment, a paraffinic component crystallizes and grows up, which results in deposition of wax.

[0003] In a fuel supply system such as the automotive engine, a fuel filter is generally disposed upstream of a fuel pump so as to prevent the fuel pump from being contaminated with foreign substance. When the wax deposits upstream of the fuel filter, it is trapped by a filter element in the fuel filter. For this reason, at an initial stage of starting of the engine under the low-temperature environment, the filter element may be clogged in a short time due to the wax. In this case, the amount of fuel supplied to an injector becomes insufficient, which results in reduction of an engine output.

[0004] Patent Document 1 discloses a configuration to eliminate clogging of a filter element caused by deposition of wax. Specifically, in a fuel supply device including a fuel filter upstream of a fuel pump, surplus fuel from a common rail and leaked fuel from an injector and from the fuel pump are mixed with fuel from a fuel tank so that the mixed fuel passes through the fuel filter. That is, the fuel is heated by the surplus fuel and the leaked fuel each having a relatively high temperature, which melts the wax and eliminates the clogging of the filter element.

Prior Art Document

Patent Document

[0005] [Patent Document 1] JP 2014-020221 A

Summary of Invention

Problem to Be Solved by Invention

[0006] It is conceivable to dispose two fuel filters upstream of the fuel pump in consideration of use of low-quality fuel that contains not a few foreign substances.

[0007] In this case, the fuel passes through the filter elements of the respective fuel filters by a negative suction pressure of the fuel pump. Like this, when using the negative suction pressure of the fuel pump, it is difficult to sufficiently obtain a pressure to make the fuel pass through the filter elements (i.e., since fuel suction by the fuel pump makes the fuel pass through the filter elements, the pressure to pass the fuel is likely to be insufficient).

As a result, even when the amount of foreign substances trapped by the filter elements is relatively small, the amount of fuel that passes through the filter elements may decrease. Therefore, even when each amount of foreign substances trapped by the corresponding filter element of each of the fuel filters is relatively small, it is necessary to replace each filter element. That is, the greater number of the fuel filters are used, the more replacement parts are required.

[0008] Furthermore, in a state in which the wax deposits in the fuel under the low-temperature environment, all filter elements of the fuel filters may be clogged.

[0009] The present invention was made in consideration of the above circumstances, an object of which is to provide a fuel supply device for an internal combustion engine, which includes a plurality of fuel filters and is capable of reducing the number of replacement parts and suppressing clogging of filter elements caused by deposition of wax.

Means for Solving Problem

[0010] In order to resolve the above problems, the present invention is predicated on a fuel supply device for an internal combustion engine, which includes: a fuel supply path configured to supply fuel in a fuel tank to a fuel injection valve using a fuel pump. In the fuel supply device for an internal combustion engine, the fuel supply path includes: a first fuel filter that is disposed upstream of the fuel pump and that has a first filter element; and a second fuel filter that is disposed downstream of the fuel pump and that has a second filter element. Furthermore, a fuel return path is disposed so that fuel discharged from the fuel pump is returned, via the second fuel filter, to an upstream side of the first filter element in the first fuel filter.

[0011] With the above constituent features, when the fuel passes through the second filter element of the second fuel filter, the fuel is caused to pass through the second filter element by a discharge pressure of the fuel pump. Thus, in the case using the discharge pressure of the fuel pump, it is possible to sufficiently increase the pressure to cause the fuel to pass through the filter element (second filter element) (i.e., since the fuel pump pushes the fuel into the second filter element so that the fuel passes through the second filter element, the pressure to cause the fuel to pass through can be sufficiently increased, compared with the case in which the fuel pump sucks the fuel to cause it to pass through). For this reason, even when the amount of foreign substances trapped by the second filter element is relatively large, the fuel can pass through the second filter element. As a result, it is not necessary to replace the second filter element. Thus, the number of replacement parts can be reduced while a plurality of fuel filters is provided (i.e., the number of the replacement parts can be reduced compared with the case in which all of the filter elements of the fuel filters are needed to be replaced).

[0012] Also, the temperature of the fuel that reaches

the second fuel filter is relatively high because it is pressurized by the fuel pump. Then, the fuel is returned to the upstream side of the first filter element inside the first fuel filter via the fuel return path. Thus, the temperature on the upstream side of the first filter element can be increased. Accordingly, even when the first filter element is clogged by wax, it is possible to quickly melt the wax to eliminate the clogging. Also, when the first filter element is not clogged by the wax, it is possible to prevent the wax deposition, thereby preventing the clogging of the first filter element due to the wax.

[0013] Also, it is preferable that: the second filter element is housed in a filter casing of the second fuel filter; the filter casing includes an air vent valve having a suction port and a discharge port each opened toward a corresponding side of the filter casing; and a fuel return pipe forming the fuel return path is connected to the discharge port of the air vent valve.

[0014] With the above configuration, part of the fuel in the filter casing of the second fuel filter can be discharged from the air vent valve to the fuel return pipe. Thus, the air vent valve, which is provided to discharge air from the second fuel filter, can be used also as a fuel outlet port through which the fuel is returned to the first fuel filter. As a result, it is not necessary to provide, in the second fuel filter, a fuel outlet port dedicated to returning the fuel to the first fuel filter. Thus, the configuration of the second fuel filter can be simplified.

[0015] Also, it is preferable that the first fuel filter includes: a returned fuel heater configured to mix fuel introduced from the fuel tank with fuel introduced via the fuel return path so that the mixed fuel flows into the first filter element; and a thermostat valve configured to switch between an open state and a closed state according to whether a temperature of the fuel introduced via the fuel return path is not more than a predetermined temperature or is more than the predetermined temperature. Preferably, the thermostat valve is connected to: a fuel path that is further connected to the returned fuel heater; and a fuel path that is further connected to the fuel tank. Also preferably, when the temperature of the fuel introduced via the fuel return path is not more than the predetermined temperature, the fuel introduced via the fuel return path flows into the returned fuel heater via the thermostat valve, and when the temperature of the fuel introduced via the fuel return path is more than the predetermined temperature, the fuel introduced via the fuel return path flows, via the thermostat valve, into the fuel tank bypassing the returned fuel heater.

[0016] With the above configuration, when the temperature of the fuel introduced to the first fuel filter via the fuel return path is more than the predetermined temperature, the thermostat valve operates so that the fuel is returned to the fuel tank bypassing the returned fuel heater. That is, the fuel introduced via the fuel return path is returned to the fuel tank without passing through the first filter element, which prevents the temperature of the fuel passing through the first filter element from excessively

increasing. Thus, degradation of the first filter element can be prevented and performance of the first fuel filter can be maintained.

[0017] Also, it is preferable that the second fuel filter is integrally attached to a body of the internal combustion engine.

[0018] With the above configuration, the heat of the body of the internal combustion engine (heat generated in the combustion stroke in the cylinders) can be easily transmitted to the second fuel filter. Thus, the heat of the body of the internal combustion engine can also increase the temperature of the fuel that is returned to the upstream side of the first filter element via the fuel return path. In the result, it is possible to reliably eliminate and prevent the clogging of the first filter element (clogging due to the wax).

Advantageous Effects of Invention

[0019] In the present invention, the fuel filters are disposed respectively upstream and downstream of the fuel pump so that the fuel is returned from the downstream second fuel filter to the upstream side of the first filter element inside the upstream first fuel filter. For this reason, even when the amount of foreign substances trapped by the second fuel filter is relatively large, the fuel can pass through the second fuel filter. As a result, it is not necessary to replace the filter element of the second fuel filter, which results in reduction of the number of replacement parts. Also, the fuel returned to the first fuel filter can increase the temperature on the upstream side of the first filter element. Therefore, it is possible to eliminate and prevent the clogging of the first filter element due to the wax.

Brief Description of Drawings

[0020]

[FIG. 1] FIG. 1 is a schematic configuration diagram showing a fuel supply device for a diesel engine according to an embodiment.

[FIG. 2] FIG. 2 is a perspective view showing an engine body by virtual lines to explain a position where a second fuel filter is disposed.

[FIG. 3] FIG. 3 is a diagram corresponding to FIG. 1 to show a flow of fuel in a state in which a temperature of the fuel that is returned to a first fuel filter is not more than a predetermined temperature.

[FIG. 4] FIG. 4 is a diagram corresponding to FIG. 1 to show the flow of the fuel in a state in which the temperature of the fuel that is returned to the first fuel filter is more than the predetermined temperature.

Description of Embodiments

[0021] Hereinafter, description will be given on an em-

bodiment of the present invention with reference to the drawings. In this embodiment, the present invention is applied to a fuel supply device for a four-cylinder diesel engine that is mounted on a vehicle.

(Overall Configuration of Fuel Supply Device)

[0022] FIG. 1 is a schematic configuration diagram showing a fuel supply device 1 for a diesel engine according to this embodiment. As shown in FIG. 1, the fuel supply device 1 includes: a fuel tank 2; a first fuel filter 3; a feed pump (fuel pump in the present invention) 4; a second fuel filter 5; a high-pressure fuel pump 6; a common rail 7; and injectors (fuel injection valves) 8.

[0023] The fuel tank 2 is connected to the first fuel filter 3 via a first fuel pipe 101. At the upstream end of the first fuel pipe 101, a strainer 101a is disposed. The first fuel filter 3 is connected to the feed pump 4 via a second fuel pipe 102. The feed pump 4 is connected to the second fuel filter 5 via a third fuel pipe 103. The second fuel filter 5 is connected to the high-pressure fuel pump 6 via a fourth fuel pipe 104. The high-pressure fuel pump 6 is connected to the common rail 7 via a fifth fuel pipe 105. The common rail 7 is connected to each injector 8 corresponding to each of four cylinders by respective sixth fuel pipes 106.

[0024] The components 2 to 8 are thus connected via the first to sixth fuel pipes 101 to 106. Thus, a fuel supply path 100 is configured to supply fuel in the fuel tank 2 to the injectors 8.

[0025] Fuel (diesel fuel) is stored in the fuel tank 2.

[0026] In a filter casing 31 of the first fuel filter 3, a filter element (first filter element) 32 is housed. The first fuel filter 3 traps, using the filter element 32, foreign substances contained in the fuel that is sucked from the fuel tank 2 by an operation of the feed pump 4, and thus purifies the fuel. The specific configuration of the first fuel filter 3 will be described later.

[0027] The feed pump 4 is constituted by a trochoid pump, a vane pump or the like. The feed pump 4 is operated by a rotational force of a crankshaft (not shown) of the engine, which is transmitted via a chain and the like. The feed pump 4 has a discharge pressure, for example, of about 400 kPa. However, the discharge pressure is not limited thereto.

[0028] As is the case of the first fuel filter 3, in a filter casing 51 of the second fuel filter 5, a filter element (second filter element) 52 is housed. The second fuel filter 5 traps, using the filter element 52, foreign substances contained in the fuel that is discharged from the feed pump 4, and thus purifies the fuel. The specific configuration of the second fuel filter 5 will also be described later.

[0029] The high-pressure fuel pump 6 is constituted by a plunger pump in which reciprocal motion of a plunger 62 inside a cylinder 61 makes the volume of a pressurizing chamber 63 variable so as to increase the pressure of the fuel. That is, the rotational force of the crankshaft (not shown) of the engine is transmitted to a camshaft

64 via the chain and the like, thus the camshaft 64 is rotated so as to reciprocally move the plunger 62 inside the cylinder 61, thereby increasing the pressure of the fuel. When the pressure of the fuel exceeds a predetermined value, a check valve 65 is opened so as to discharge the fuel into the fifth fuel pipe 105. The amount of the fuel to be discharged is adjustable by opening/closing operations of an electromagnetic spill valve 66. Since opening/closing control of the electromagnetic spill valve 66 is well known, the description thereon is omitted here. Note that the high-pressure fuel pump 6 is not limited to the plunger pump. Various kinds of pumps may be applied.

[0030] The common rail 7 accumulates high-pressure fuel supplied from the high-pressure fuel pump 6. A relief valve 71 is attached to the common rail 7. The relief valve 71 is opened to decrease a rail pressure when the rail pressure increases and reaches not less than a predetermined pressure.

[0031] Each of the injectors 8 is provided relative to a corresponding cylinder of the engine. The injectors 8 operate, responding to instructions from an engine ECU (electronic control unit, not shown), to inject the fuel into the respective cylinders.

[0032] The high-pressure fuel pump 6, the relief valve 71 of the common rail 7 and the injectors 8 are connected to a fuel return pipe 107. One end of the fuel return pipe 107 is connected to the first fuel filter 3. The other end of the fuel return pipe 107 is branched so as to be connected respectively, as above described, to the high-pressure fuel pump 6, the relief valve 71 of the common rail 7 and the injectors 8. Thus, the fuel return pipe 107 returns the following, to the first fuel filter 3: fuel that leaks from a gap between the cylinder 61 and the plunger 62 of the high-pressure fuel pump 6; surplus fuel in the common rail 7 (i.e., fuel discharged by opening of the relief valve 71); and leaked fuel from the injectors 8. The flow of the fuel returned to the first fuel filter 3 will be described later.

(First Fuel Filter)

[0033] Here, the first fuel filter 3 is described. As described above, the first fuel filter 3 is disposed upstream of the feed pump 4 on the fuel supply path 100, and has a configuration in which the filter element 32 is housed in the filter casing 31.

[0034] The filter casing 31 is a case having a substantially rectangular parallelepiped shape. The first fuel pipe 101 is connected to an upper portion of one side surface 31a (right side surface in FIG. 1) of the filter casing 31. Also, the second fuel pipe 102 is connected to an upper portion of another side surface (front side surface in FIG. 1, not shown) of the filter casing 31.

[0035] The filter element 32 is housed in the filter casing 31, in a portion lower than the respective positions at which the filter casing 31 is connected to the first fuel pipe 101 and the second fuel pipe 102. The filter element

32 has a substantially cylindrical shape and has a fuel introduction path 32a vertically penetrating the central portion thereof. The fuel flowed from the first fuel pipe 101 to the filter casing 31 flows down into the fuel introduction path 32a (more specifically, passes through a returned fuel heater 34 described later and flows down into the fuel introduction path 32a), and after that, the fuel passes through the filter element 32 from the bottom to the top. During passing through the filter element 32, foreign substances contained in the fuel are trapped by the filter element 32.

[0036] A fuel flow-in chamber 32b is formed on the top of the filter element 32. The second fuel pipe 102 is connected to the fuel flow-in chamber 32b. Thus, the fuel passed through the filter element 32 flows into the second fuel pipe 102 via the fuel flow-in chamber 32b, and further flows into the feed pump 4.

[0037] Also, in an upper space of the filter casing 31 of the first fuel filter 3 (i.e., the space above the fuel flow-in chamber 32b), a thermostat valve 33 and the returned fuel heater 34 (shown in the virtual line in FIG. 1) are disposed.

[0038] The fuel return pipe 107 penetrates a top surface 31b of the filter casing 31 and is inserted into the filter casing 31, thus connected to the thermostat valve 33. The thermostat valve 33 is configured so that a valving element (valve) is opened/closed by thermowax as a driving source, the thermowax expanding/contracting according to the temperature of the fuel that flows from the fuel return pipe 107. The thermostat valve 33 is connected to: a first pipe 33a that is further connected to the returned fuel heater 34; and a second pipe 33b that is further connected to the fuel tank 2. The upstream end of the second pipe 33b penetrates a side surface 31c (left side surface in FIG. 1) of the filter casing 31 of the first fuel filter 3 so as to be connected to the thermostat valve 33, and the downstream end of the second pipe 33b is positioned inside the fuel tank 2. The first pipe 33a constitutes "a fuel path via which the thermostat valve is connected to the returned fuel heater" in the present invention. Also, the second pipe 33b constitutes "a fuel path via which the thermostat valve is connected to the fuel tank" in the present invention.

[0039] When the temperature of the fuel that flows from the fuel return pipe 107 into the first fuel filter 3 (fuel that flows into the thermostat valve 33) is not more than a predetermined temperature and accordingly the valving element of the thermostat valve 33 cuts off the communication of the fuel return pipe 107 with the second pipe 33b due to contraction of the thermowax, the thermostat valve 33 allows the communication of the fuel return pipe 107 with the first pipe 33a. That is, the fuel from the fuel return pipe 107 is allowed to flow into the returned fuel heater 34.

[0040] On the other hand, when the temperature of the fuel that flows from the fuel return pipe 107 into the first fuel filter 3 is more than the predetermined temperature and accordingly the valving element of the thermostat

valve 33 allows the communication of the fuel return pipe 107 with the second pipe 33b due to expansion of the thermowax, the thermostat valve 33 cuts off the communication of the fuel return pipe 107 with the first pipe 33a and allows the communication of the fuel return pipe 107 with the second pipe 33b. That is, the fuel from the fuel return pipe 107 is allowed to bypass the returned fuel heater 34 so as to flow into the fuel tank 2.

[0041] The above-mentioned predetermined temperature is set to lower than a temperature that causes degradation of the filter element 32 (the lower limit temperature causing the degradation of the filter element 32) by a predetermined temperature. That is, if there is a possibility that the temperature of the fuel flowing from the fuel return pipe 107 into the first fuel filter 3 reaches the temperature that causes degradation of the filter element 32, the valving element of the thermostat valve 33 allows the communication of the fuel return pipe 107 with the second pipe 33b, while cutting off the communication of the fuel return pipe 107 with the first pipe 33a, so that the fuel flowed from the fuel return pipe 107 bypasses the returned fuel heater 34 and flows into the fuel tank 2, without flowing into the filter element 32.

[0042] The returned fuel heater 34 is configured to mix the fuel that is returned from the fuel return pipe 107 to the first fuel filter 3 (fuel that is introduced via the thermostat valve 33) with the fuel that is introduced from the first fuel pipe 101 (fuel that is introduced from the fuel tank 2 via the first fuel pipe 101). That is, in the state in which the valving element of the thermostat valve 33 is closed (i.e., the state in which the fuel return pipe 107 communicates with the first pipe 33a), the returned fuel heater 34 mixes the fuel that is introduced from the fuel tank 2 via the first fuel pipe 101 and that has a relatively low temperature with the fuel that is returned from the fuel return pipe 107 and that has a relatively high temperature. Thus, the temperature of the fuel that flows into the filter element 32 is raised (specifically, it is raised higher than the temperature of the fuel in the fuel tank 2).

[0043] The returned fuel heater 34 may also be configured as a case to mix the fuel that is introduced from the fuel return pipe 107 into the first fuel filter 3 with the fuel that is introduced from the first fuel pipe 101 into the first fuel filter 3, or may simply be configured as a space that an open end of the first pipe 33a and an open end of the first fuel pipe 101 face.

(Second Fuel Filter)

[0044] Here, the second fuel filter 5 is described. As described above, the second fuel filter 5 is disposed downstream of the feed pump 4, and has a configuration in which the filter element 52 is housed in the filter casing 51.

[0045] The filter casing 51 is a case having a substantially rectangular parallelepiped shape. The third fuel pipe 103 is connected to one side surface 51a (left side surface in FIG. 1) of the filter casing 51. Also, the fourth fuel

pipe 104 is connected to the other side surface 51b (right side surface in FIG. 1) of the filter casing 51. With such a configuration, the fuel that flows from the third fuel pipe 103 into the filter casing 51 passes through the filter element 52. During passing through the filter element 52, foreign substances contained in the fuel are trapped by the filter element 52. Thus, the fuel passed through the filter element 52 flows into the high-pressure fuel pump 6 via the fourth fuel pipe 104.

[0046] When the fuel passes through the filter element 52 of the second fuel filter 5, the fuel is caused to pass through the filter element 52 by the discharge pressure of the feed pump 4. Thus, in the case using the discharge pressure of the feed pump 4, it is possible to sufficiently increase the pressure to cause the fuel to pass through the filter element 52 (i.e., since the feed pump 4 pushes the fuel into the filter element 52 so that the fuel passes through the filter element 52, the pressure to cause the fuel to pass through can be sufficiently increased, compared with the case in which the feed pump 4 sucks the fuel to cause it to pass through). For this reason, even when the amount of foreign substances trapped by the filter element 52 is relatively large, the fuel can pass through the filter element 52. As a result, it is not necessary to replace the filter element 52.

[0047] An air vent valve 53 is disposed in the filter casing 51 of the second fuel filter 5. The air vent valve 53 is to discharge the air in the filter casing 51 of the second fuel filter 5. In the filter casing 51, the air vent valve 53 is disposed in the vicinity of the one side surface 51a (side surface to which the third fuel pipe 103 is connected), i.e., disposed upstream of the filter element 52 in the fuel flow direction.

[0048] One of the characteristics of this embodiment is that a suction port 53a of the air vent valve 53 is opened toward the center in the filter casing 51 (as shown in FIG. 1, the air vent valve 53 is disposed leftward in the filter casing 51, accordingly, the suction port 53a is opened toward the right side in the Figure), while a discharge port 53b is opened toward the side (left side in the Figure) of the filter casing 51. Therefore, the suction port 53a of the air vent valve 53 faces the fuel in the filter casing 51, unless a large volume of air exists in the filter casing 51 of the second fuel filter 5. The discharge port 53b of the air vent valve 53 is connected to a fuel return pipe 108 (fuel return pipe that forms part of a fuel return path in the present invention). The fuel return pipe 108 is constituted by a pipe that penetrates the side surface 51a (left side surface in FIG. 1) of the filter casing 51 of the second fuel filter 5 and is connected to the discharge port 53b of the air vent valve 53. The fuel return pipe 108 is connected to the fuel return pipe 107. That is, the fuel return pipe 108 connects the discharge port 53b of the air vent valve 53 and the fuel return pipe 107.

[0049] A check valve is housed in the air vent valve 53, which is opened according to the increase of the pressure inside the filter casing 51. Therefore, when the pressure inside the filter casing 51 reaches a predetermined

pressure, the check valve is opened so as to discharge the air in the filter casing 51, if exists, to the fuel return pipe 108. As described above, the suction port 53a of the air vent valve 53 is opened toward the center in the filter casing 51, while the discharge port 53b is opened toward the side of the filter casing 51. Thus, when the check valve is opened, part of the fuel in the filter casing 51 is also discharged from the air vent valve 53 to the fuel return pipe 108. As described above, the fuel return pipe 108 is connected to the fuel return pipe 107. Thus, the fuel discharged from the air vent valve 53 to the fuel return pipe 108 joins the fuel that flows in the fuel return pipe 107 so as to flow into the first fuel filter 3 (more specifically, into the thermostat valve 33 disposed in the filter casing 31).

[0050] In this way, part of the fuel in the filter casing 51 of the second fuel filter 5 flows into the filter casing 31 of the first fuel filter 3. Thus, the fuel return pipe 108 and part of the fuel return pipe 107 (corresponding to the part from the connecting position of the fuel return pipe 108 to the filter casing 31 of the first fuel filter 3) constitute the fuel return path (fuel return path to return the fuel, which is discharged from the fuel pump, to the upstream side of the first filter element of the first fuel filter via the second fuel filter) in the present invention.

[0051] A differential pressure to open the check valve of the air vent valve 53 (differential pressure between the suction port 53a side and the discharge port 53b side) is set equal to or slightly lower than a differential pressure caused by an operation of the feed pump 4, i.e., the differential pressure between the inside of the filter casing 51 and the inside of the third fuel pipe 103. Thus, when the fuel is discharged from the feed pump 4 according to its operation, the check valve is continuously opened and the fuel is continuously discharged from the air vent valve 53 to the fuel return pipe 108. That is, the fuel is continuously discharged from the second fuel filter 5 to the fuel return pipe 108, which joins the fuel that flows in the fuel return pipe 107 (i.e., the above-described leaked fuel and surplus fuel) so as to flow into the first fuel filter 3. In the case where the leaked fuel and the surplus fuel are not generated, only the fuel discharged from the air vent valve 53 flows into the first fuel filter 3 via the fuel return pipe 108 and the fuel return pipe 107. In this embodiment, the position where the air vent valve 53 is disposed, and the respective inner diameters and the like of the suction port 53a, the discharge port 53b and the fuel return pipe 108 are set based on experiments and the like, so that the amount of fuel that is discharged from the second fuel filter 5 to the fuel return pipe 108 is set at approximately 5 % of the amount of fuel that flows from the third fuel pipe 103 into the second fuel filter 5. However, the value is not limited thereto, it may be set appropriately.

[0052] As shown in FIG. 2 (perspective view showing an engine body E by virtual lines to explain the position where the second fuel filter 5 is disposed), the second fuel filter 5 is integrally attached to the engine body E. Specifically, the second fuel filter 5 is secured to a cylin-

der block CB by bolts so that a side surface (back surface in FIG. 2) of the second fuel filter 5 makes contact with a side surface of the cylinder block CB. Thus, the heat of the engine body E (heat generated in the combustion stroke in the cylinders) is easily transmitted to the second fuel filter 5.

(Fuel Supply Operation)

[0053] Here, description is given on an operation for supplying the fuel of the fuel supply device 1 configured as described above. The following two states are separately described: the state in which the temperature of the fuel that flows from the fuel return pipe 107 into the first fuel filter 3 is not more than the predetermined temperature; and the state in which the above temperature is more than the predetermined temperature. Examples of the states in which the temperature of the fuel is not more than the predetermined temperature include an initial stage of cold starting of the engine. Examples of the states in which the temperature of the fuel is more than the predetermined temperature include completion of warming-up operation of the engine.

-State in Which Temperature of Fuel Is Not More Than Predetermined Temperature-

[0054] FIG. 3 is a diagram corresponding to FIG. 1 to show a flow of the fuel in the state in which the temperature of the fuel that flows into the first fuel filter 3 is not more than the predetermined temperature. Solid line arrows in the Figure indicate the flow of the fuel supplied to the injectors 8. Broken line arrows in the Figure indicate the flow of the fuel that flows into the first fuel filter 3 via the fuel return pipe 107 and the fuel return pipe 108.

[0055] When the temperature of the fuel that flows from the fuel return pipe 107 into the first fuel filter 3 is not more than the predetermined temperature, the valving element is closed due to contraction of the thermowax of the thermostat valve 33. In this state, the thermostat valve 33 allows the communication of the fuel return pipe 107 with the first pipe 33a. That is, the fuel from the fuel return pipe 107 is allowed to flow into the returned fuel heater 34.

[0056] In the fuel return pipe 107, the following flows: the fuel that leaks from the gap between the cylinder 61 and the plunger 62 of the high-pressure fuel pump 6 (i.e., leaked fuel); the surplus fuel inside the common rail 7 (i.e., fuel discharged by opening of the relief valve 71); and the leaked fuel from the injectors 8. Also, in this embodiment, the fuel discharged from the air vent valve 53 of the second fuel filter 5 flows into the fuel return pipe 107 via the fuel return pipe 108. Thus, the fuel discharged from the air vent valve 53 is returned, together with the leaked fuel and the surplus fuel, to the first fuel filter 3 via the fuel return pipe 107. In the result, a large amount of fuel having a relatively high temperature is reliably returned to the first fuel filter 3.

[0057] As described above, the thermostat valve 33 allows the communication of the fuel return pipe 107 with the first pipe 33a. Thus, the returned fuel heater 34 mixes the fuel that is returned from the fuel return pipe 107 to the first fuel filter 3 with the fuel that is introduced from the first fuel pipe 101 (fuel that is introduced from the fuel tank 2 via the first fuel pipe 101). Accordingly, the fuel having a relatively high temperature flows into the filter element 32.

[0058] Under the low-temperature environment, a paraffinic component in the fuel crystallizes and grows up to result in deposition of wax, which may cause the clogging of the filter element 32. In this embodiment, the fuel having a relatively high temperature flows into the upstream side of the filter element 32 of the first fuel filter 3, and furthermore a relatively large amount of fuel is returned to the first fuel filter 3 via the fuel return pipe 107. Accordingly, the temperature on the upstream side of the filter element 32 can be increased. Thus, even when the filter element 32 is clogged by the wax, it is possible to melt quickly the wax to eliminate the clogging of the filter element 32. For example, when the wax deposits in the fuel under the outside air temperature of -15°C, the fuel discharged from the feed pump 4 has the temperature of 10°C (for this reason, the fuel flowing in the fuel return pipe 108 also has the temperature of approximately 10°C), and the leaked fuel and the like from the high-pressure fuel pump 6 have the temperature of 15°C. Thus, these fuels each having a relatively high temperature (i.e., temperature higher than, for example, -10°C at which the wax deposits) increase the temperature on the upstream side of the filter element 32. Therefore, even when the filter element 32 is clogged by the wax, it is possible to melt the wax to eliminate the clogging. Also, when the filter element 32 is not clogged by the wax, it is possible to prevent the wax deposition, thereby preventing the clogging of the filter element 32 due to the wax.

-State in Which Temperature of Fuel Is More Than Predetermined Temperature-

[0059] FIG. 4 is a diagram corresponding to FIG. 1 to show the flow of the fuel in a state in which the temperature of the fuel that flows into the first fuel filter 3 is more than the predetermined temperature. Solid line arrows in the Figure indicate the flow of the fuel supplied to the injectors 8. Broken line arrows in the Figure indicate the flow of the fuel that flows into the first fuel filter 3 via the fuel return pipe 107 and the fuel return pipe 108, and that is returned to the fuel tank 2.

[0060] When the temperature of the fuel that flows from the fuel return pipe 107 into the first fuel filter 3 is more than the predetermined temperature, the valving element is opened due to expansion of the thermowax of the thermostat valve 33. In this state, the thermostat valve 33 allows the communication of the fuel return pipe 107 with the second pipe 33b. That is, the fuel from the fuel return

pipe 107 is allowed to bypass the returned fuel heater 34 so as to flow into the fuel tank 2.

[0061] In this case, the fuel flows into the first fuel filter 3 via the fuel return pipe 107 and the fuel return pipe 108 similarly to the case as described above, i.e., the case in which the temperature of the fuel is not more than the predetermined temperature. However, since the thermostat valve 33 allows the communication of the fuel return pipe 107 with the second pipe 33b while cutting off the communication of the fuel return pipe 107 with the first pipe 33a, the total amount of the fuel flowed into the thermostat valve 33 is returned to the fuel tank 2 via the second pipe 33b.

[0062] As a result, only the fuel sucked from the fuel tank 2 passes through the filter element 32 of the first fuel filter 3. That is, the fuel that is returned from the fuel return pipe 107 and that has a relatively high temperature does not pass through directly the filter element 32 without going through the fuel tank 2, which prevents the temperature of the fuel passing through the filter element 32 from excessively increasing. Thus, degradation of the filter element 32 can be prevented and performance of the first fuel filter 3 can be maintained.

[0063] As described above, in this embodiment, when the fuel passes through the filter element 52 of the second fuel filter 5, the fuel is caused to pass through the filter element 52 by the discharge pressure of the feed pump 4. Thus, in the case using the discharge pressure of the feed pump 4, it is possible to sufficiently increase the pressure to cause the fuel to pass through the filter element 52 (i.e., since the feed pump 4 pushes the fuel into the filter element 52 so that the fuel passes through the filter element 52, the pressure to cause the fuel to pass through can be sufficiently increased). For this reason, even when the amount of foreign substances trapped by the filter element 52 is relatively large, the fuel can pass through the filter element 52. As a result, it is not necessary to replace the filter element 52. Thus, the number of replacement parts can be reduced while two fuel filters 3 and 5 are provided (i.e., the number of the replacement parts can be reduced compared with the case in which all of the filter elements are needed to be replaced). Note that the filter element 32 of the first fuel filter 3 is a part that is needed to be replaced.

[0064] Also, in this embodiment, the temperature of the fuel that reaches the second fuel filter 5 is relatively high because it is pressured by the feed pump 4. As described above, the second fuel filter 5 is integrally attached to the engine body E. Thus, the heat of the engine body E (heat generated in the combustion stroke in the cylinders) is transmitted to the second fuel filter 5, which also makes the temperature of the fuel in the second fuel filter 5 relatively high. Then, the fuel is returned to the upstream side of the filter element 32 inside the first fuel filter 3 via the fuel return pipe 108 and the fuel return pipe 107. Such returned fuel increases, along with the leaked fuel and the surplus fuel, the temperature on the upstream side of the filter element 32. Therefore, even when

the filter element 32 is clogged by the wax, it is possible to quickly melt the wax to eliminate the clogging. Also, when the filter element 32 is not clogged by the wax, it is possible to prevent the wax deposition, thereby preventing the clogging of the filter element 32 due to the wax.

[0065] Furthermore, in this embodiment, the air vent valve 53, which is provided to discharge the air from the second fuel filter 5, is used also as a fuel outlet port through which the fuel is returned to the first fuel filter 3. As a result, it is not necessary to provide, in the second fuel filter 5, a fuel outlet port dedicated to returning the fuel to the first fuel filter 3. Thus, the configuration of the second fuel filter 5 can be simplified.

-Other Embodiments-

[0066] In the embodiment as described above, the fuel discharged from the second fuel filter 5 to the fuel return pipe 108 is mixed with the fuel that flows in the fuel return pipe 107 so that the mixed fuel flows into the first fuel filter 3. However, the present invention is not limited thereto. The fuel discharged from the second fuel filter 5 to the fuel return pipe 108 can flow into the first fuel filter 3 without being mixed with the other fuel.

[0067] Also in the embodiment as described above, the fuel supply path 100 includes only two fuel filters, i.e., the first fuel filter 3 and the second fuel filter 5. However, the fuel supply path 100 may include, in addition to the above two fuel filters, another fuel filter. In this case, when a fuel filter is disposed upstream of the feed pump 4, a filter element of such a fuel filter is a part that is needed to be replaced. On the other hand, when a fuel filter is disposed downstream of the feed pump 4, a filter element of such a fuel filter is a part that is not needed to be replaced, as mentioned above.

[0068] Also in the embodiment as describe above, the description was given on the case in which the present invention is applied to a fuel supply device for a four-cylinder diesel engine that is mounted on a vehicle. However, the present invention is not limited thereto. It may be applied to a fuel supply device for a diesel engine that is mounted on something other than the vehicle. Also, the present invention may be applied to an engine having less than four cylinders or an engine having more than four cylinders.

Industrial Applicability

[0069] The present invention may be applied to a fuel supply device for a diesel engine that is mounted on a vehicle.

Reference Signs List

[0070]

1 Fuel supply device

2	Fuel tank	
3	First fuel filter	
32	First filter element	
33	Thermostat valve	5
33a	First pipe	
33b	Second pipe	
34	Returned fuel heater	
4	Feed pump (fuel pump)	
5	Second fuel filter	10
51	Filter casing	
52	Second filter element	
53	Air vent valve	
53a	Suction port	
53b	Discharge port	15
8	Injector (fuel injection valve)	
100	Fuel supply path	
107	Fuel return pipe (fuel return path)	
108	Fuel return pipe (fuel return path)	
E	Engine body (internal combustion engine body)	20

Claims

1. A fuel supply device for an internal combustion engine, the fuel supply device comprising: a fuel supply path configured to supply fuel in a fuel tank to a fuel injection valve using a fuel pump, **characterized in that:**

the fuel supply path includes: a first fuel filter that is disposed upstream of the fuel pump and that has a first filter element; and a second fuel filter that is disposed downstream of the fuel pump and that has a second filter element; and a fuel return path is disposed so that fuel discharged from the fuel pump is returned, via the second fuel filter, to an upstream side of the first filter element in the first fuel filter.
2. The fuel supply device for an internal combustion engine according to claim 1, wherein the second filter element is housed in a filter casing of the second fuel filter, wherein the filter casing includes an air vent valve having a suction port and a discharge port each opened toward a corresponding side of the filter casing, and wherein a fuel return pipe forming the fuel return path is connected to the discharge port of the air vent valve.
3. The fuel supply device for an internal combustion engine according to claim 1 or 2, wherein the first fuel filter includes: a returned fuel heater configured to mix fuel introduced from the fuel tank with fuel introduced via the fuel return path so that the mixed fuel flows into the first filter element;

and a thermostat valve configured to switch between an open state and a closed state according to whether a temperature of the fuel introduced via the fuel return path is not more than a predetermined temperature or is more than the predetermined temperature, wherein the thermostat valve is connected to: a fuel path that is further connected to the returned fuel heater; and a fuel path that is further connected to the fuel tank, and wherein, when the temperature of the fuel introduced via the fuel return path is not more than the predetermined temperature, the fuel introduced via the fuel return path flows into the returned fuel heater via the thermostat valve, and when the temperature of the fuel introduced via the fuel return path is more than the predetermined temperature, the fuel introduced via the fuel return path flows, via the thermostat valve, into the fuel tank bypassing the returned fuel heater.

4. The fuel supply device for an internal combustion engine according to claim 1, 2 or 3, wherein the second fuel filter is integrally attached to a body of the internal combustion engine.

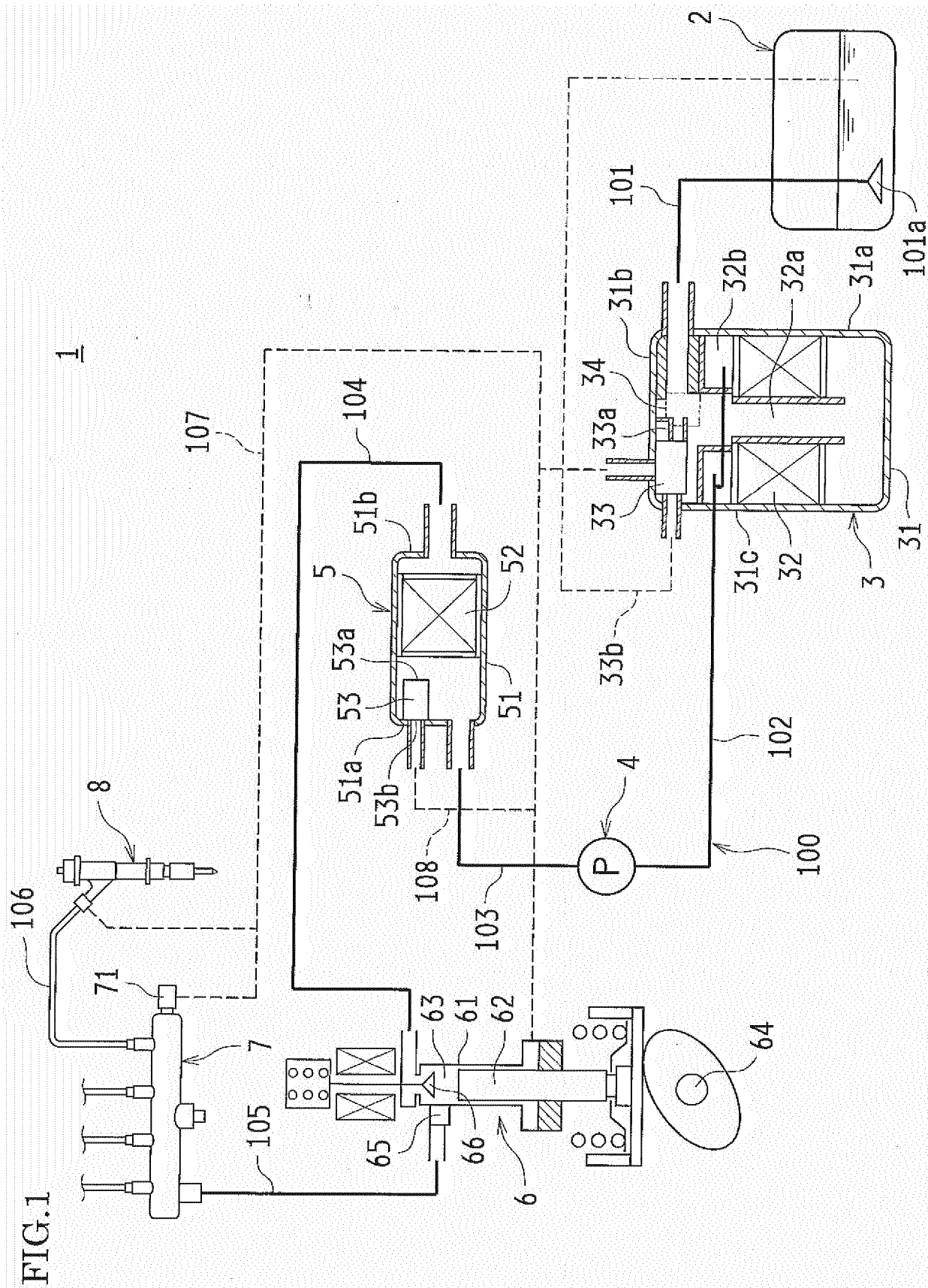


FIG.2

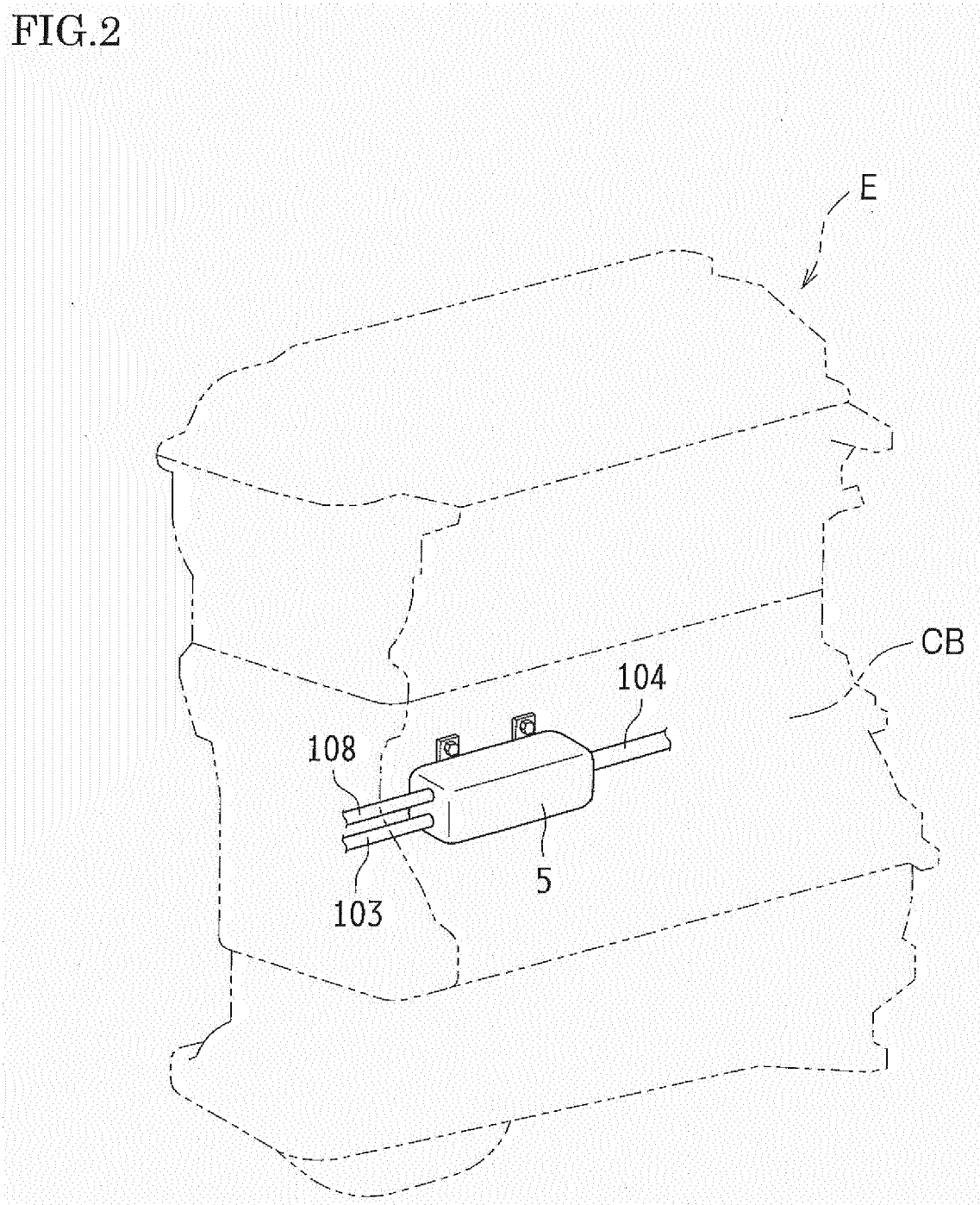
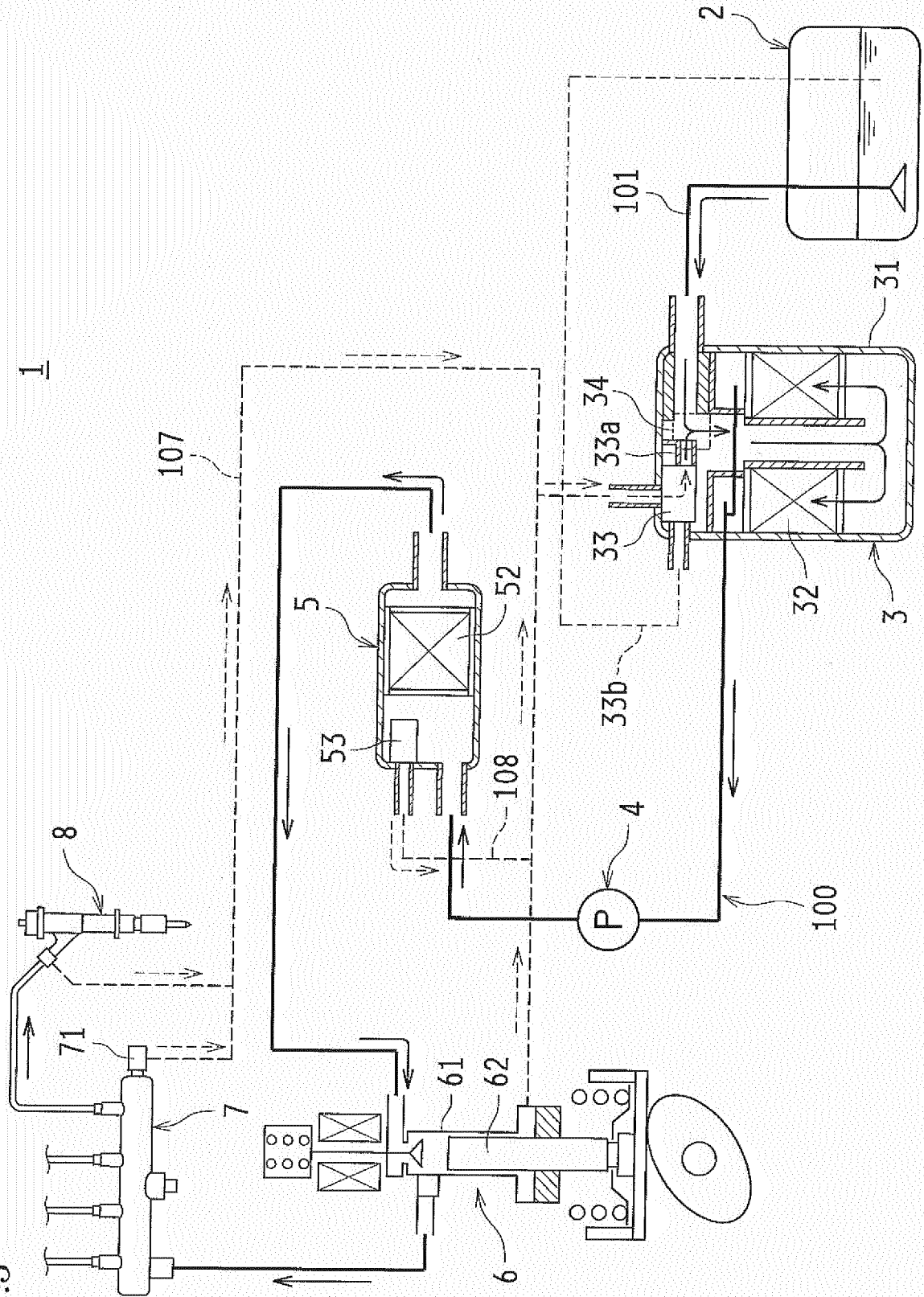
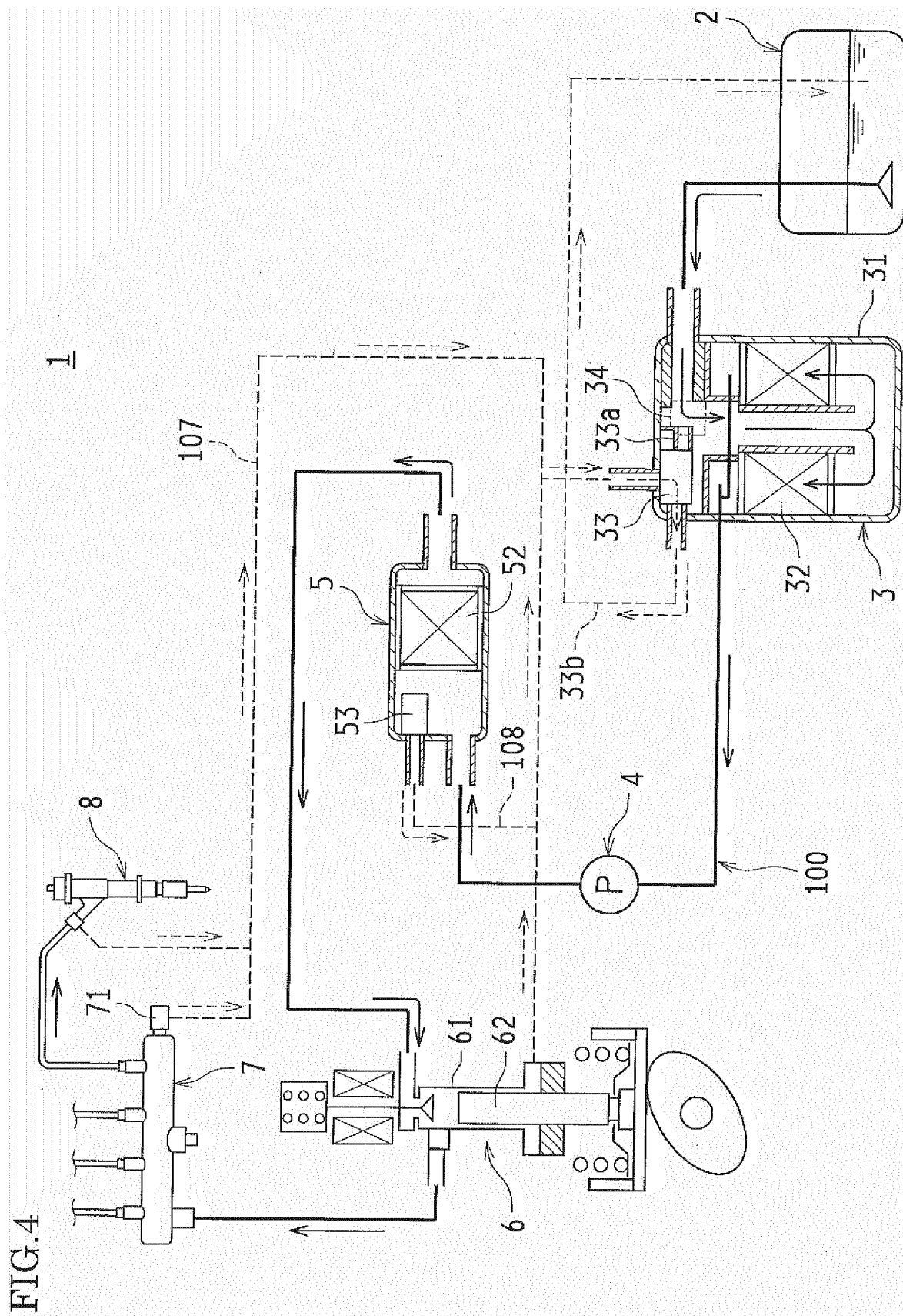


FIG.3







EUROPEAN SEARCH REPORT

Application Number
EP 16 16 4218

5

10

15

20

25

30

35

40

45

50

55

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	DE 10 2013 210973 A1 (MAHLE INT GMBH [DE]) 18 December 2014 (2014-12-18)	1,3	INV. F02M37/00 F02M37/22
A	* abstract * * figures 1, 2 * * paragraph [0008] * * paragraph [0020] - paragraph [0029] *	4	ADD. B01D35/00 B01D35/18 F02M55/00 F02M31/14
X	US 2008/156295 A1 (SUZUKI MASASHI [JP] ET AL) 3 July 2008 (2008-07-03)	1,2,4	
	* abstract * * figures 1-8 * * paragraph [0047] - paragraph [0085] *		
X	GB 2 309 176 A (MANN & HUMMEL FILTER [DE]) 23 July 1997 (1997-07-23)	1,2,4	
A	* abstract * * figures 1-5 * * page 6 - page 10 *	3	
A	US 4 997 555 A (CHURCH JOHN F [US] ET AL) 5 March 1991 (1991-03-05)	1,2,4	TECHNICAL FIELDS SEARCHED (IPC)
	* abstract * * figures 1-7 * * column 2 - column 6 *		F02M B01D
A	EP 0 984 157 A1 (FILTRAUTO [FR]) 8 March 2000 (2000-03-08)	3	
	* abstract * * figures 1-3 * * claim 1 *		
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 8 September 2016	Examiner Juvenelle, Cyril
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

EPO FORM 1503 03.82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 16 16 4218

5

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

08-09-2016

10

15

20

25

30

35

40

45

50

55

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE 102013210973 A1	18-12-2014	CN 105229292 A	06-01-2016
		DE 102013210973 A1	18-12-2014
		EP 3008325 A1	20-04-2016
		JP 2016523327 A	08-08-2016
		US 2016108871 A1	21-04-2016
		WO 2014198687 A1	18-12-2014

US 2008156295 A1	03-07-2008	DE 102007000855 A1	03-07-2008
		US 2008156295 A1	03-07-2008

GB 2309176 A	23-07-1997	BR 9700093 A	22-09-1998
		CA 2195113 A1	21-07-1997
		CZ 9700109 A3	13-08-1997
		DE 19602082 A1	24-07-1997
		ES 2135314 A1	16-10-1999
		FR 2743849 A1	25-07-1997
		GB 2309176 A	23-07-1997
		US 5896846 A	27-04-1999

US 4997555 A	05-03-1991	NONE	

EP 0984157 A1	08-03-2000	DE 69909693 D1	28-08-2003
		DE 69909693 T2	15-04-2004
		EP 0984157 A1	08-03-2000
		ES 2204085 T3	16-04-2004
		FR 2782750 A1	03-03-2000

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- JP 2014020221 A [0005]