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(71) Applicant: **Delphi Technologies, Inc.**
Troy, MI 48007 (US)

(72) Inventor: **Wood, C.**
Rainham, Kent ME8 9BY (GB)

(74) Representative: **Keltie, David Arthur et al**
David Keltie Associates
Fleet Place House
2 Fleet Place
London EC4M 7ET (GB)

(54) **Fuel pump**

(57) A fuel pump for use in a common rail fuel system for an internal combustion engine comprises a plurality of pump assemblies (12), each of which has a pumping plunger (14) which is reciprocable within a respective plunger bore under the influence of an associated drive arrangement (20, 22, 24) to perform a pumping cycle during which fuel within a respective pumping chamber (18) is pressurised to a relatively high level. The drive arrangement for each pump assembly is arranged to impart reciprocating movement to the associated pumping plunger (14) upon co-operation with a cam surface. At least one of the pumping plunger (14) and the plunger bore is provided with a collection groove (50) which is registerable with a return passage (52) during at least a period of the pumping cycle, the return passage (52) being provided with a venturi device (54) in communication with a low pressure drain (58) such that, in use, leakage fuel within the collection groove (50) is permitted to flow to the low pressure drain through the venturi device (54).

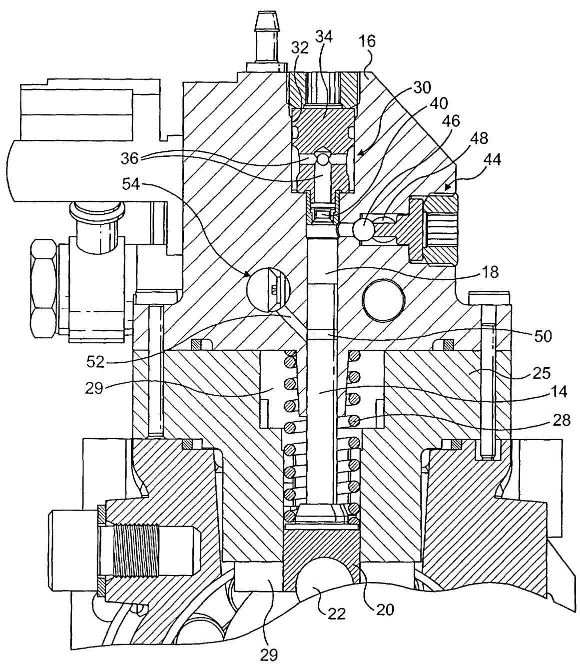

FIG. 2

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Description

[0001] The invention relates to a fuel pump for use in supplying high pressure fuel to a fuel injection system of a compression ignition internal combustion engine. In particular, the invention relates to a fuel pump having a plurality of pump assemblies for supplying high pressure fuel to a common rail fuel injection system.

[0002] One known common rail fuel pump assembly includes a plurality of plungers, which are driven by means of a cam drive arrangement so as to pressurise fuel within respective pumping chambers for delivery to the common rail. The cam drive arrangement includes a common eccentric cam surface, rotatable by means of a drive shaft, and it is common for such pumps to include three (or more) plungers which are equi-angularly spaced around the drive shaft. The cam surface is cooperable with all three of the plungers to cause phased, cyclical movement of the plungers and, hence, pressurisation of fuel within the pumping chambers. High pressure fuel is delivered to a common rail for supply to the downstream fuel injectors.

[0003] Pump assemblies are also known in which a plurality of in-line pumping elements are provided, each of which is driven by means of an associated shoe and roller arrangement. The roller of each arrangement cooperates with an associated cam, each of which is mounted upon a common drive shaft. The shoe is arranged to cooperage with the pumping element such that, as the rollers ride over their respective cam surfaces, the shoes are driven to cause the plungers to reciprocate within plunger bores, thereby causing pressurisation of fuel within the associated pumping chamber.

[0004] For some pump applications, it can be desirable for the shoe and roller arrangement to be lubricated with engine oil to improve durability. Contamination of engine oil can occur, however, if fuel leaks from the pumping chambers, down the plunger bores into the cam follower mechanism.

[0005] It is an object of the present invention to avoid this problem.

[0006] According to the present invention, there is provided a fuel pump comprising:

a plurality of pump assemblies, each of which comprises a pumping plunger which is reciprocable within a respective plunger bore under the influence of an associated drive arrangement to perform a pumping cycle during which fuel within a respective pumping chamber is pressurised to a relatively high level, each drive arrangement being arranged to impart reciprocating movement to the associated pumping plunger upon cooperation with a cam surface,

wherein at least one of the pumping plunger and the plunger bore is provided with a collection groove which is registerable with a return passage during at least a period of the pumping cycle, the return passage being provided with a venturi device in communication with a low pressure drain such that, in use, leakage fuel flow into the collection groove is permitted to flow to the low pressure drain through the venturi device.

[0007] The pump assembly of the present invention provides the advantage that any leakage flow from the pumping chamber into the collection groove is drained through the return passage, to the venturi passage and to low pressure. Contamination of engine oil, used for lubrication of the drive arrangement, with fuel from the pumping chambers is therefore avoided.

[0008] Preferably, the collection groove takes the form of an annular or arcuate groove or recess provided on the surface of the plunger. As the return passage is brought into registration with the collection groove, leakage fuel collected within the collection groove is permitted to flow to the low pressure drain passage through the venturi device. In this embodiment the collection groove therefore communicates with the return passage during only a part of the pumping cycle.

[0009] Alternatively, the collection groove may be defined, in part, by an arcuate or annular groove or recess provided in the plunger bore, such that the collection groove communicates with the return passage at all times (i.e. throughout the full pumping cycle).

[0010] In one particular embodiment of the invention, one collection groove is defined in the plunger bore and another collection groove is defined on the plunger itself.

[0011] Preferably, each drive arrangement includes a shoe and roller arrangement, including a roller which is cooperable with an associated cam member to drive movement of a shoe.

[0012] Alternatively, each drive arrangement includes a tappet and roller arrangement, including a roller which is cooperable with an associated cam member to drive movement of a tappet coupled to the pumping plunger.

[0013] The pump may be an "in-line" pump, wherein each drive arrangement is cooperable with an associated cam member. In this embodiment, the cam members associated with each drive arrangement are axially spaced along a common drive shaft.

[0014] Alternatively, each drive arrangement is cooperable with a cam surface common to each of the pump assemblies. For example, the pump assemblies may be radially mounted upon a drive shaft carrying a cam surface located radially inwards of the drive arrangements.

[0015] The fuel pump may further comprise an inlet valve arrangement for controlling fuel flow into the pumping chamber and an outlet delivery valve arrangement for controlling the flow out of the pumping chamber to a high pressure supply passage.

[0016] In one embodiment, the inlet valve arrangement includes a plate valve which is engageable with a valve seating to control fuel flow into the pumping chamber.

[0017] In one embodiment, the outlet delivery valve arrangement includes a ball valve which is engageable with a further valve seating to control fuel flow out of the pumping chamber.

[0018] The accumulator volume typically takes the form of what is commonly referred to as a "common rail" containing fuel at high pressure for delivery to a plurality of injectors.

[0019] The invention will now be described, by way of example only, with reference to the accompanying figures in which:

Figure 1 is a sectional view of a fuel pump in accordance with the present invention,

Figure 2 is a sectional view, along line V-V, of the fuel pump in Figure 1, and

Figure 3 is a sectional view, along line W-W, of the fuel pump in Figures 1 and 2 to illustrate a venturi device forming part of the pump.

[0020] Referring to the accompanying drawings, a fuel pump, referred to generally as 10, includes three pump assemblies 12, which are arranged to supply fuel at high pressure to a common rail (not shown) of a fuel injection system for a diesel engine. Each pump assembly is substantially identical to the others, and so only one will be described in further detail. Each pump assembly 12 includes a pumping element or plunger 14 which is moveable within a plunger bore provided in a first pump housing 16 to cause pressurisation of fuel within an associated pumping chamber 18. The plunger 14 is driven through a pumping cycle, including a pumping stroke and a return stroke, by means of a drive arrangement including a shoe 20 which is cooperable with a base end of the plunger 14 and a roller 22 which cooperates with a surface of a cam 24 mounted upon a drive shaft 26 that is common to each pump assembly. The drive shaft 26 extends through a second pump housing 27 and is driven, in use, so that the roller 22 rides over the cam surface and drives the shoe 20 and plunger 14 to reduce the volume of the pumping chamber 18. A return spring 28, through which the plunger 14 extends, is arranged to act on the shoe 20 such that, when the plunger 14 completes the pumping stroke, the plunger 14 is urged outwardly from its bore by a force due to the return spring 28 acting in combination with residual fuel pressure within the pumping chamber 18.

[0021] The second pump housing 27 is secured to an intermediate housing 25 mounted upon the first pump housing 16. The intermediate housing 25 is shaped to define a chamber 29 through which a lower portion of the plunger 14 extends. The chamber 29 is partially filled with engine oil which serves to lubricate the shoe and roller arrangement 20, 22 so as to improve durability.

[0022] Each pump assembly 12 includes a respective shoe and roller arrangement driven by an associated shaft mounted cam 24. The cams 24 are axially spaced along the drive shaft 26 and arranged such that the plungers 14 reciprocate within their respective bores in a cyclical, phased manner as the drive shaft 26 is rotated, in use, at a speed associated with the engine.

[0023] In use, fuel is supplied by means of a transfer pump 38 (as shown in Figure 1) to an inlet metering valve (not shown), which is arranged to vary the rate of flow of fuel into the pumping chamber 18 through an inlet passage 19. The pressure of fuel supplied by the inlet metering valve is typically referred to as "metered fuel pressure" and is delivered to the pumping chamber 18 though an inlet check valve arrangement 30 provided in the inlet passage 19.

[0024] As can be seen most clearly in Figure 2, the inlet check valve arrangement 30 is housed within a bore 32 provided in the first pump housing 16. An insert 34 is received within the bore 32 and is provided with drillings 36 through which fuel at metered pressure from the inlet passage 19 is supplied to the pumping chamber 18. The inlet check valve arrangement 30 includes a plate valve 40, preferably biased against a first valve seating by means of a spring (not shown), and moveable away from the seating under the influence of fuel pressure supplied through the drillings 36 to permit fuel at metered pressure to flow into the pumping chamber 18.

[0025] The transfer pump 38 typically takes the form of a conventional vane pump mounted upon the drive shaft 26 at a rear end of the second pump housing 27, as shown in Figure 1. The transfer pump 38 is arranged to supply fuel to the inlet metering valve at a pressure (commonly referred to as "transfer pressure") dependent upon the speed of rotation of the shaft 26. The pump assembly 12 is also provided with an outlet delivery valve arrangement 44, including a ball valve 46 which is engageable with a second valve seating to control fuel flow between the pumping chamber 18 and a high pressure supply passage 48 (not visible in Figure 1) to the common rail. The ball valve 46 is preferably biased towards the second valve seating by means of a second spring (not shown) arranged such that, when fuel pressure within the pumping chamber 18 is increased beyond a predetermined amount, the force acting on the ball valve 46 due to fuel pressure within the pumping chamber 18 is sufficient to overcome fuel pressure within the supply passage 48 acting in combination with the second spring, to permit fuel at high pressure to flow to the common rail.

[0026] The plunger 14 is provided with an annular groove or recess part way along its axial length to define a collection chamber or groove 50 for leakage flow from the pumping chamber 18, between the plunger bore and the plunger 14. The groove 50 is preferably annular, but may alternatively be of part-annular or arcuate form and is positioned such that, at the end of the return stroke when the plunger 14 occupies its outermost position within the plunger bore, the collection groove 50 is brought into registration with a return passage 52 provided with a venturi device 54, as shown more clearly in Figure 3.

[0027] The venturi device 54 includes a venturi pump body 55 received within a flow path between the return passage 52 and a low pressure drain passage 58 in communication with a low pressure drain or reservoir (not shown). The venturi device 54 includes an inlet region 54a an outlet region 54b and a throat region 54c arranged intermediate the inlet and outlet regions 54a, 54b. The throat region 54c is provided with a feed port 56 which communicates with one end of the return passage 52. In addition to communicating with the collection groove 50 provided on the plunger 14, the return passage 52 also communicates, at its end remote from the venturi device 54, with a backleak connector 57 associated with a fuel injector (not shown) of the fuel injection system.

[0028] The inlet region 54a communicates with an inlet flow passage 59 defined within the venturi pump body 55, which receives fuel at transfer pressure from the transfer pump 38 to provide a continuous flow of fuel through the venturi device 54 to the drain passage 58 and, hence, to low pressure.

[0029] The throat region 54c has a substantially uniform, relatively small diameter along its axial length. A part of the throat region 54c immediately downstream of the feed port 56 is of greater cross-sectional area than the part of the throat region 54c immediately upstream of the feed port 56, and therefore any flow of fuel through the feed port 56 does not result in a significant increase in the velocity of fuel flowing past the end of the feed port 56. A relatively large magnitude vacuum is therefore drawn within the throat region 54c. As both the injector backleak connector 57 and the plunger leakage collection groove 50 communicate with the return passage 52, which in turn communicates with the vacuum region of the venturi device 54, a vacuum will be drawn in the collection groove 50. A vacuum will also be drawn in the injector flow paths and/or chambers which communicate with the backleak connector 57 of the injector.

[0030] One advantage provided by this arrangement in that any leakage flow of fuel from the pumping chamber 18 into the collection groove 50 during the pumping cycle, which may otherwise contaminate lubricating oil within the chamber 29, is drawn through the return passage 52, through the venturi device 54 to the drain passage 58 and, hence, to low pressure.

[0031] At the start of the pumping cycle, the pumping plunger 14 adopts its innermost position within the plunger bore (i.e. uppermost position in the orientation in Figure 1) and fuel pressure within the pumping chamber 18 is high due to the pressurisation caused by the previous pumping stroke. The outlet valve arrangement 44 is closed due to the equalisation of fuel pressures in the pumping chamber 18 and the high pressure supply passage 48.

[0032] Upon commencement of its return stroke, the plunger member 14 is initially allowed to retract from the plunger bore due to decompression within the pumping chamber 18 and retraction of the shoe 20 under the force of the return spring 28 as the roller 22 rides over the surface of the cam 24. As the pumping chamber 18 is decompressed, a point will be reached at which the pressure in the pumping chamber 18 falls below the pressure required to lift the plate valve 40 from the first valve seating due to the flow of fuel from the inlet passage 19 through the drillings 36 in the insert 34, and the next filling phase commences.

[0033] At the end of the return stroke, the collection groove 50 on the plunger is brought into communication with the return passage 52 so that any fuel which has collected within the groove 50 due to leakage through the plunger bore will be drawn through the return passage 52, through the venturi device 54 and through the drain passage 58 to low pressure. The groove 50 is shaped and positioned on the plunger so that it is only at the end of the return stroke, just prior to the pumping stroke, that the groove 50 registers with the return passage 52.

[0034] During the filling phase, the ball 46 of the delivery valve arrangement 44 remains seated against the second valve seating due to high pressure fuel within the high pressure supply passage 48 and due to the force of the outlet valve spring.

[0035] After the plunger 14 reaches its outermost position within the plunger bore, the roller 22 is urged in an upward direction (in the illustration shown in Figures 1 and 2) as it follows the surface of the cam 24, thereby causing the shoe 20 to be urged in an upwards direction and, hence, the pumping plunger 14 to be driven inwardly within the plunger bore. Fuel within the pumping chamber 18 is unable to flow past the closed delivery valve arrangement 44 due to fuel pressure within the high pressure supply passage 48, and hence fuel pressure within the pumping chamber 18 starts to increase. Moreover, a point will be reached part way through the pumping stroke at which the inlet plate valve 40 is urged against its seating due to increasing fuel pressure within the pumping chamber 18 (assisting the force of the spring, if provided), thereby preventing the further flow of fuel into or out of the pumping chamber 18 through the drillings 36.

[0036] As the pumping stroke continues, fuel within the pumping chamber 18 is pressurised to a sufficiently high level to cause the ball 46 of the delivery valve arrangement 44 to lift from the second valve seating, thereby permitting pressurised fuel to flow from the pumping chamber 18 into the high pressure supply passage 48 and, hence, to the common rail.

[0037] At the end of the pumping stroke, when the pumping plunger 14 reaches the end of its range of travel, the ball 46 will be urged against the second valve seating due to high pressure fuel within the high pressure supply passage 48 and the force of the outlet valve spring, thereby holding fuel pressure within the high pressure flow passage 48 at a high level.

[0038] The injector backleak connector 57 in Figure 3 is typically of conventional form, for example as described in EP 0893598 A, and communicates with an injector backleak connection line. By drawing a vacuum to the injector backleak connection line, consistency between injections can be improved as reduced fuel pressure within the backleak connection line causes fuel and air to form a foam which is capable of absorbing any pressure spikes occurring during the operation of each injector.

[0039] In an alternative embodiment to that described previously, the groove 50 may be shaped and positioned so that it registers with the return passage 52 throughout the full pumping cycle, rather than during only a part of the pumping cycle.

[0040] In a further alternative embodiment of the invention (not shown), the drive arrangement includes a tappet and roller arrangement, wherein a tappet is coupled to a base region of the plunger and is cooperable with a roller, in use, to impart a drive force to the plunger as the drive shaft rotates and the respective roller rides over the respective cam surface.

[0041] In another embodiment, a collection groove of annular or arcuate form may be provided in the plunger bore, such that it communicates constantly (i.e. throughout the full pumping cycle) with the return passage 52. In this embodiment, the plunger 14 may also be shaped to include a groove on its outer surface which registers with the collection groove in the plunger bore during a portion of the pumping cycle. This provides the advantage that there is additional volume for leakage fuel to collect in before passing to the return passage 52, either via the collection groove on the plunger or via the collection groove in the plunger bore.

[0042] It will be appreciated that although the pump described with reference to the accompanying drawings has three pump assemblies 12, a greater or lesser number of pump assemblies may be mounted about the drive shaft 26. Furthermore, although the pump described is of type including a plurality of in-line pumping elements, the invention is equally applicable to a radial fuel pump, in which a plurality of pump assemblies are mounted radially upon a common drive shaft carrying a single, central cam which is cooperable with the drive arrangement of each pump assembly to impart reciprocal movement to their plungers in a phased, cyclical manner. The invention also extends to radial pumps of the type including an outer cam defining an internal cam surface which co-operates with the drive arrangements of a plurality of radially inward pump assemblies.

Claims

1. A fuel pump for use in an accumulator fuel system for an internal combustion engine, the fuel pump comprising:

a plurality of pump assemblies (12), each of which comprises a pumping plunger (14) which is reciprocable within a respective plunger bore under the influence of an associated drive arrangement (20, 22) to perform a pumping cycle during which fuel within a respective pumping chamber (18) is pressurised to a relatively high level,

the drive arrangement (20, 22) for each pump assembly being arranged to impart reciprocating movement to the associated pumping plunger (14) upon co-operation with a cam surface,

wherein at least one of the pumping plunger (14) and the plunger bore is provided with a collection groove (50) which is registerable with a return passage (52) during at least a period of the pumping cycle, the return passage (52) being provided with a venturi device (54) in communication with a low pressure drain such that, in use, leakage fuel flow into the collection groove (50) is permitted to flow to the low pressure drain through the venturi device (54).

2. A fuel pump as claimed in Claim 1, wherein the collection groove (50) is defined, in part, by an arcuate or annular groove or recess provided on the surface of the plunger (14).

3. A fuel pump as claimed in Claim 2, wherein the collection groove is shaped and positioned such that it is brought into registration with the return passage (52) during only a part of the pumping cycle.

4. A fuel pump as claimed in Claim 3, wherein the collection groove (50) is positioned on the plunger (14) so that it is brought into registration with the return passage (52) only at the end of a plunger return stroke.

5. A fuel pump as claimed in Claim 2, wherein the collection groove (50) is shaped and positioned such that it communicates with the return passage (52) throughout the full pumping cycle.

6. A fuel pump as claimed in Claim 1, wherein the collection groove (50) is defined, at least in part, by an arcuate or annular groove or recess provided in the plunger bore such that it communicates with the return passage (52) throughout the full pumping cycle.

7. A fuel pump as claimed in any one of Claims 1 to 6, wherein one collection groove (50) is defined in the plunger bore and another collection groove is defined in the plunger (14).

8. A fuel pump as claimed in any one of Claims 1 to 7, wherein each drive arrangement includes a shoe and roller arrangement (20, 22), including a roller

(22) which is cooperable with the cam surface to drive movement of a shoe (20).

9. A fuel pump as claimed in any one of Claims 1 to 7, wherein each drive arrangement includes a tappet and roller arrangement, including a roller which is cooperable with the cam surface to drive movement of a tappet coupled to the pumping plunger (14).

10. A fuel pump as claimed in any one of Claims 1 to 9, wherein each drive arrangement is cooperable with an associated cam member (24), the cam members being axially spaced along a common drive shaft (26).

11. A fuel pump as claimed in any one of Claims 1 to 9, wherein each drive arrangement is cooperable with a cam surface common to each of the pump assemblies.

12. A fuel pump as claimed in Claim 11, wherein the pump assemblies (12) are radially mounted upon a drive shaft (26) carrying a cam surface located radially inwards of the drive arrangements.

13. A fuel pump as claimed in any one of Claims 1 to 12, including an inlet valve arrangement (30, 40) for controlling fuel flow into the pumping chamber (18) and an outlet delivery valve arrangement (44, 46) for controlling fuel flow out of the pumping chamber (18) to a high pressure supply passage .

14. A fuel pump as claimed in Claim 13, wherein the inlet valve arrangement includes a plate valve (40) which is engageable with a valve seating to control fuel flow into the pumping chamber (18).

15. A fuel pump as claimed in Claim 13 or Claim 14, wherein the outlet delivery valve arrangement (44) includes a ball valve (46) which is engageable with a further valve seating to control fuel flow out of the pumping chamber (18).

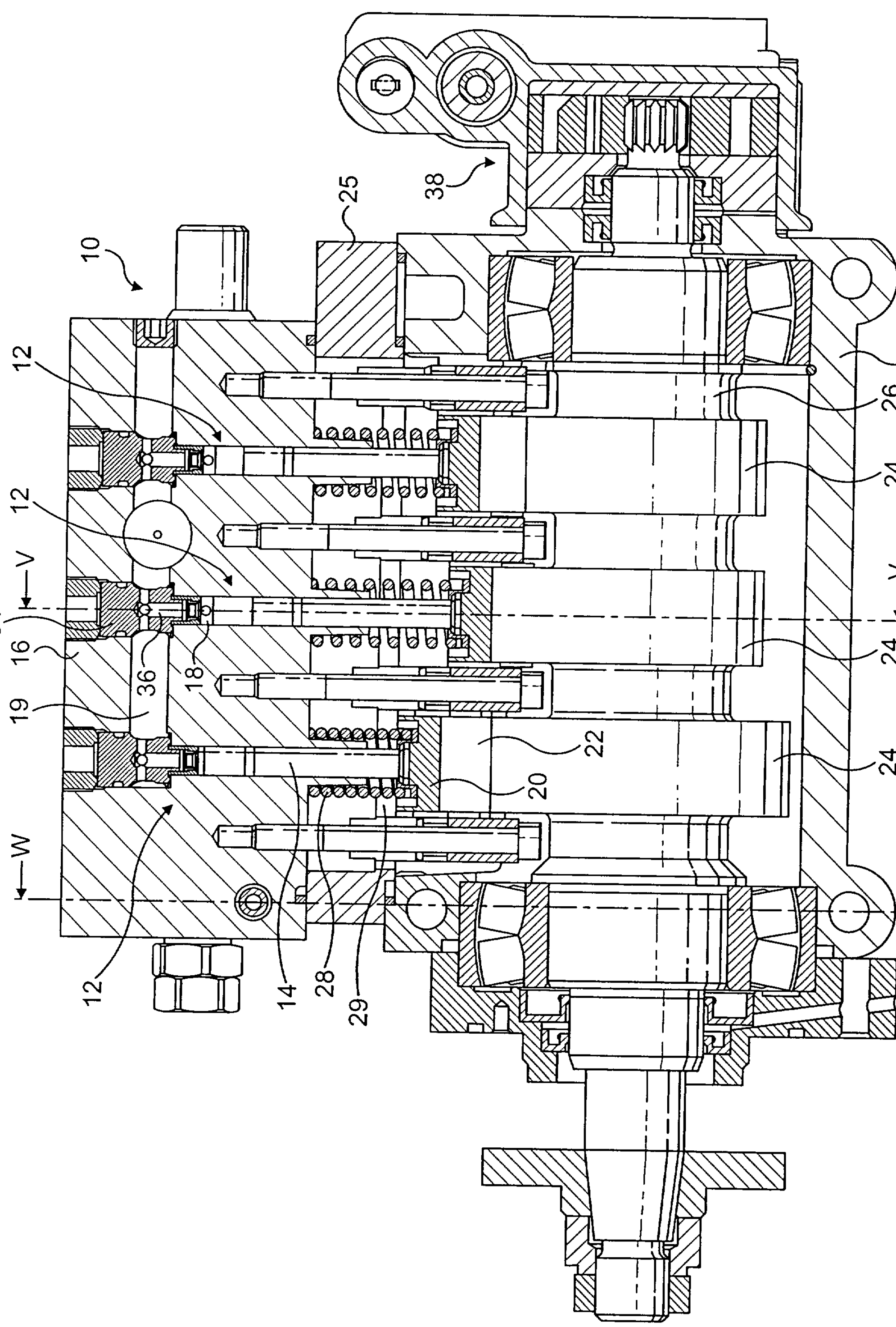

FIG. 1

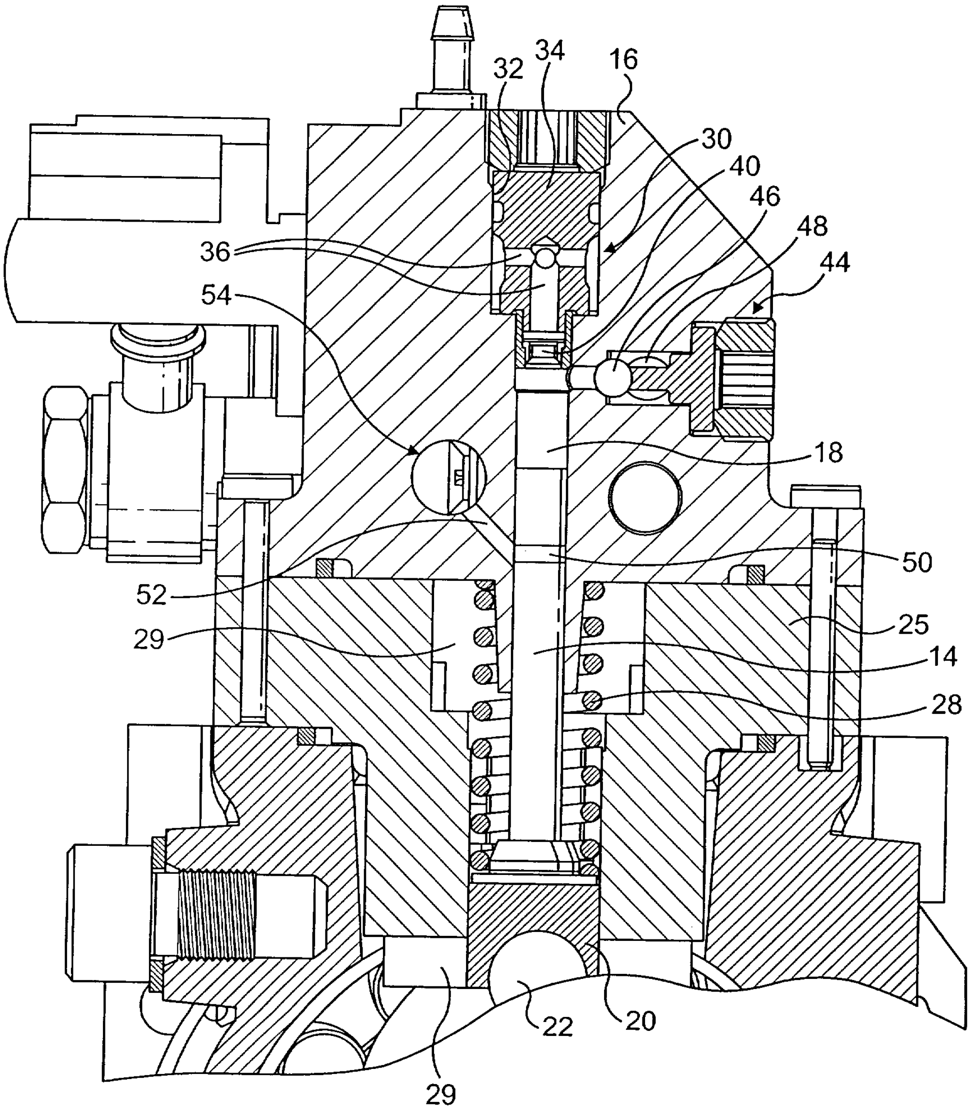

FIG. 2

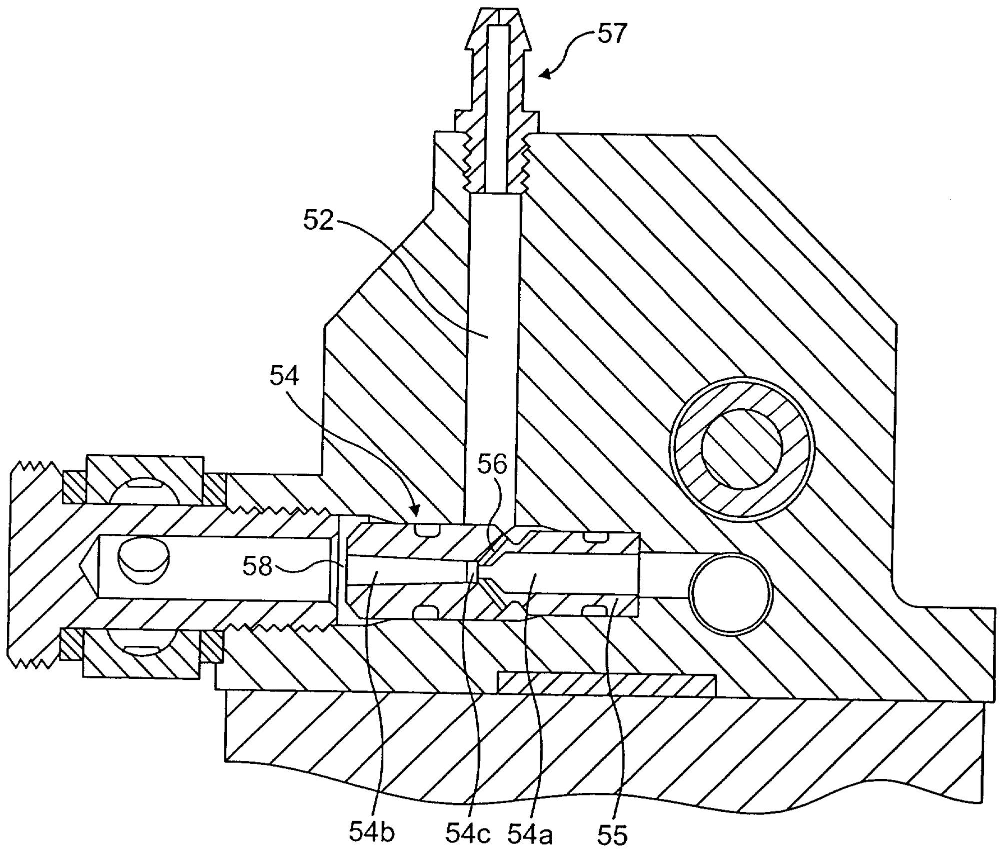

FIG. 3