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(54) **Fuel injector**

(57) A fuel injector comprising a valve needle (14) which is slidable within a bore (12) and engageable with a valve needle seating to control fuel delivery through an outlet opening and a first supply passage (18) for delivering fuel under high pressure to the bore from a pump chamber (20). The valve needle (14) has a surface associated therewith which is exposed to fuel pressure within a control chamber (32). A control valve arrangement (36) is provided to control fuel pressure within the control chamber so as to control movement of the valve needle (14) relative to the valve needle seating. A spill/fill passage (28) is provided through which fuel at relatively low pressure is delivered to the pump chamber (20) under the control of a spill valve arrangement (60). The spill/fill passage is provided with a venturi pump (48) in communication with a backleak passage (46) through which fuel flows to a low pressure fuel reservoir.

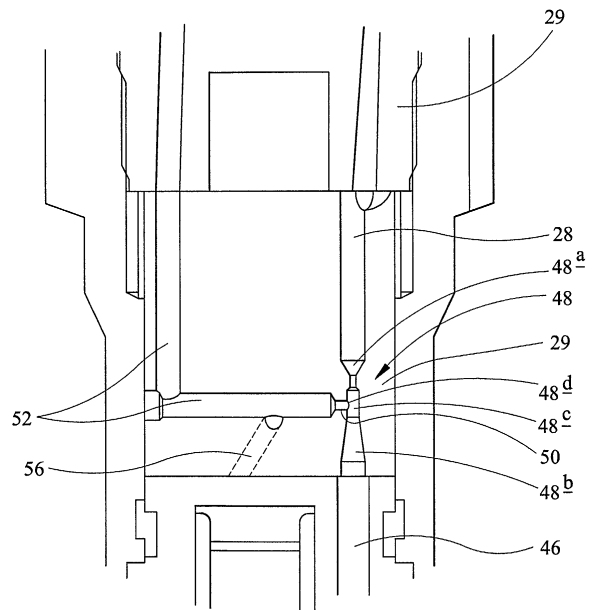


FIG 3

Description

[0001] This invention relates to a fuel injector for use in supplying fuel under pressure to a combustion space of an associated internal combustion engine. In particular, the invention relates to a unit/pump injector of the type including a pump for supplying fuel exclusively to the injection nozzle of the injector, and not to other injection nozzles associated with the engine.

[0002] In known unit/pump injectors, for example as shown in EP 0840003, the timing of fuel injection from an injection nozzle is controlled independently of the timing of commencement of fuel pressurisation by the pump by controlling the fuel pressure within a control chamber of the nozzle. The injection nozzle includes a valve needle which is engageable with a valve needle seating to control fuel delivery through an outlet opening of the injection nozzle. A surface associated with the valve needle is exposed to the fuel pressure within the control chamber. By appropriate control of the fuel pressure within the control chamber, the magnitude of a force urging the valve needle towards its seating can be controlled. Fuel pressure within the control chamber is controlled by means of an electromagnetically actuable three way valve operable to permit communication between the control chamber and either a supply passage containing fuel under pressure or a drain passage which communicates, in use, with a relatively low pressure fuel reservoir.

[0003] The unit/pump injector also includes a spill valve arrangement which is arranged to control communication between the low pressure fuel reservoir and a pump chamber defined, at least in part, within a bore in a pump housing. A plunger member is reciprocable within the plunger bore so as to vary the volume of the pump chamber, the spill valve arrangement being operable between an open position in which the pump chamber communicates with the low pressure reservoir, in which case reciprocal movement of the plunger member causes fuel to be displaced from the pump chamber to the low pressure fuel reservoir, and a closed position in which communication between the pump chamber and the low pressure fuel reservoir is broken. When the spill valve arrangement is closed, movement of the plunger member within the plunger bore, in a direction to reduce the volume of the pump chamber, causes fuel within the chamber to be pressurised. High pressure fuel within the pump chamber is delivered to the associated injection nozzle through a supply passage.

[0004] It is important to ensure that fuel is recirculated through the injector so as to facilitate cooling. It is therefore desirable to displace a proportion of relatively hot fuel within the unit/pump injector to a backleak connection passage, whereby the fuel can flow to the low pressure fuel reservoir, and to replace the displaced fuel with cooler fuel.

[0005] It is an object of the present invention to provide a unit/pump injector of the aforementioned type

which enables this to be achieved.

[0006] According to the present invention, there is provided a fuel injector comprising a valve needle which is slidable within a bore and engageable with a valve needle seating to control fuel delivery through an outlet opening, a first supply passage for delivering fuel under high pressure to the bore from a pump chamber, the valve needle having a surface associated therewith which is exposed to fuel pressure within a control chamber, a control valve arrangement for controlling fuel pressure within the control chamber so as to control movement of the valve needle relative to the valve needle seating, a spill/fill passage through which fuel at relatively low pressure is delivered to the pump chamber under the control of a spill valve arrangement, wherein the spill/fill passage is provided with a venturi pump in communication with a backleak passage through which fuel is able to flow to a low pressure fuel reservoir.

[0007] The venturi pump preferably includes an inlet region in communication with the spill/fill passage, an outlet region in communication with the backleak passage and a throat region intermediate the inlet and outlet regions.

[0008] Preferably, the throat region of the venturi pump is provided with a feed port in communication with a return passage, a vacuum being drawn within the return passage when fuel flows through the venturi pump.

[0009] Preferably, the spill valve arrangement includes a spill valve member which is operable under the control of a first actuator arrangement. Preferably, the first actuator arrangement includes a first energisable winding and a first armature which is coupled to the spill valve member such that energisation and de-energisation of the first winding causes the first armature, and hence the spill valve member, to move. The spill valve member is preferably arranged within a first armature chamber, the return passage being arranged to communicate with the first armature chamber such that a vacuum is drawn therein.

[0010] Communication between the return passage and the first armature chamber serves to reduce pressure waves within the first armature chamber which may otherwise cause unwanted movement of the spill valve member.

[0011] The control valve arrangement preferably includes a control valve member which is operable under the control of a second actuator arrangement. The second actuator arrangement may be an electromagnetic actuator arrangement comprising a second energisable winding and preferably including a second armature which is coupled to the control valve member. Energisation and de-energisation of the second winding causes the second armature, and hence the control valve member, to move between an open position in which the control chamber communicates with the low pressure fuel reservoir and a closed position in which communication between the control chamber and the low pressure fuel reservoir is broken, thereby to control fuel pres-

sure within the control chamber.

[0012] The second armature is preferably arranged within a second armature chamber, the return passage being arranged to communicate with the second armature chamber such that a vacuum is drawn in the second armature chamber.

[0013] The injector may also include a plunger member which is arranged to pressurise fuel within a pump chamber upon reciprocal movement of the plunger member within a plunger bore, the plunger member having, associated therewith, a leak collection chamber, preferably defined by a groove or recess provided on the plunger member, within which leakage fuel from the pump chamber collects. The leak collection chamber may be arranged to communicate with the return passage such that a vacuum is drawn therein.

[0014] Communication between the return passage and the second armature chamber to draw a vacuum in the second armature chamber reduces pressure waves within the second armature chamber which may otherwise cause unwanted movement of the control valve member.

[0015] The invention will now be described, by way of example only, with reference to the accompanying drawings in which:

Figure 1 is a first sectional view illustrating a fuel injector in accordance with an embodiment of the invention,

Figure 2 is an alternative sectional view of the fuel injector in Figure 1,

Figure 3 is an enlarged view of a part of the fuel injector in Figures 1 and 2, and

Figure 4 is an enlarged view, part in section, of a spill valve arrangement forming part of the injector in Figures 1 to 3.

[0016] The unit pump/injector illustrated in the accompanying drawings comprises an injection nozzle having a nozzle body 10 which is provided with a blind bore 12 within which a valve needle 14 is slidable. The valve needle 14 is engagable with a valve needle seating defined by the blind end of the bore 12 to control fuel delivery from a delivery chamber defined by the valve needle 14 and the bore 12, and a plurality of outlet openings (not shown) located downstream of the valve needle seating. The bore 12 is shaped to define an annular chamber 16 for receiving fuel under high pressure through a supply passage 18 defined in various housing parts of the injector. In use, the supply passage 18 receives fuel under high pressure from a pump chamber 20 defined, in part, within a plunger bore 24 provided in a pump housing 22. A plunger member 26 is reciprocable within the plunger bore 24 under the action of a cam arrangement in a conventional manner, so as to cause

pressurisation of fuel within the pump chamber 20. The plunger member 26 is provided with a groove or recess 27 to define a leak collection chamber within which leakage fuel from the pump chamber 20 collects.

[0017] The unit pump/injector includes a spill valve arrangement 60, as shown in detail in Figure 4, for controlling communication between the pump chamber 20 and a source of fuel at relatively low pressure. Typically, the spill valve arrangement 60 includes a spill valve member 62 which is coupled to a spill valve armature 64 of a first electromagnetic actuator arrangement (not shown) arranged within an actuator housing 66 adjacent the pump housing 22. Conveniently, the spill valve armature 64 is arranged within a spill valve armature chamber 68 defined in the pump housing 22. In use, movement of the spill valve armature 64, and hence of the spill valve member 62, is controlled by energising and de-energising an electromagnetic winding of the first actuator arrangement.

[0018] The spill valve member 62 is moveable within a bore 65 provided in the pump housing 22 and includes a region 62a of enlarged diameter which is engageable with a spill valve seating 65a defined by the bore 65. When the enlarged region 62a of the spill valve member 62 is moved away from the spill valve seating 65a (i.e. an open state), a drilling 67 provided in the pump housing 22 which communicates with the pump chamber 20 is able to communicate with a spill/fill passage 28 defined partially in the pump housing 22 and partially within an additional housing 29 adjacent the pump housing 22 (as shown in Figure 3). When the spill valve member 62 is in the open state, reciprocal movement of the plunger member 26 within the plunger bore 24 causes fuel to be drawn into and displaced from the pump chamber 20 through the spill/fill passage 28 and the drilling 67, and past the spill valve member seating 65a.

[0019] When the spill valve member 62 is moved into engagement with the spill valve seating 65a (i.e. a closed state) communication between the pump chamber 20 and the low pressure fuel reservoir is broken as fuel is no longer able to flow past the spill valve seating 65a. As a result, reciprocal movement of the plunger member 26 within the plunger bore 24 causes fuel within the pump chamber 20 to be pressurised. Pressurised fuel from the pump chamber 20 is supplied to the supply passage 18 for delivery to the delivery chamber of the injection nozzle.

[0020] At its end remote from the outlet openings of the injection nozzle, the nozzle body 10 abuts a further housing 30 within which a control chamber 32 for fuel is defined. The control chamber 32 receives fuel under high pressure from the supply passage 18 through a restricted drilling 33. A piston member 34 is slidable within a piston bore provided in the further housing 30. The piston member 34 is coupled to the valve needle 14, a surface of the piston member 34 being exposed to fuel pressure within the control chamber 32 such that fuel pressure within the control chamber 32 applies a force

to the piston member 34, and hence to the valve needle 14, which serves to urge the valve needle 14 against the valve needle seating. A nozzle spring is also preferably provided at the back end of the valve needle 14, which tends to urge the valve needle towards its seating. When the valve needle 14 is seated against the valve needle seating, fuel injection through the outlet openings does not take place.

[0021] The unit pump/injector also includes a control valve arrangement, referred to generally as 36, which is arranged to control communication between the control chamber 32 and the low pressure fuel reservoir. The control valve arrangement 36 is arranged within a control valve housing 44 and includes a control valve member 38 which is coupled to a control valve armature 40 forming part of a second actuator arrangement. As can be seen most clearly in Figure 2, the control valve armature 40 of the control valve arrangement 36 is arranged within a control valve armature chamber 42 defined within the control valve housing 44.

[0022] Conveniently, the actuator for the control valve arrangement 36 takes the form of an electromagnetic actuator arrangement including a second winding which is energisable to cause movement of the control valve armature 40 and, hence, movement of the control valve member 38. The control valve member 38 is moveable between an open position in which fuel is able to flow from the control chamber 32 to the low pressure fuel reservoir and a closed position in which communication between the control chamber 32 and the low pressure fuel reservoir is broken.

[0023] As can be seen mostly clearly in Figure 3, the spill/fill passage 28 is provided with a venturi pump device 48, the venturi pump 48 being arranged such that the spill/fill passage 28 communicates, through the venturi pump 48, with a backleak passage 46 defined, at least in part, within the control valve housing 44. As the spill/fill passage 28 communicates with the backleak passage 46 through the venturi pump 48, a proportion of fuel drawn into and displaced from the pump chamber 20 when the spill valve arrangement is open will escape into the backleak passage 46 at a relatively low rate and to the low pressure fuel reservoir, to be replaced by cooler fuel drawn into the spill/fill passage 28 from the low pressure fuel reservoir. The backleak passage 46 is therefore provided to facilitate the cooling of fuel within the unit pump/injector system.

[0024] The venturi pump 48 includes an inlet region 48a, an outlet region 48b and a throat region 48c arranged intermediate the inlet and outlet regions 48a, 48b. The throat region 48c is provided with a feed port 48d which communicates, through a restricted passage 50, with a return passage 52 defined by drillings provided in the additional housing 29 and the pump housing 22. The throat region 48c has a substantially uniform, relatively small diameter along its axial length. A part of the throat region 48c immediately downstream of the feed port 48d is of greater cross-sectional area than the

part of the throat region 48c immediately upstream of the feed port 48d. As the part of the throat region 48c immediately downstream of the feed port 48d is of enlarged cross-sectional area, any flow of fuel through the feed port 48d does not result in a significant increase in the velocity of fuel flowing past the end of the feed port 48d and, thus, a relatively large magnitude vacuum is drawn within the throat region 48c.

[0025] The return passage 52 communicates with the spill valve armature chamber 68 within which the spill valve armature 64 is arranged and, in addition, communicates with a branch passage 56 in communication with the control valve armature chamber 42 (as shown in Figures 1 and 2) within which the control valve armature 40 is arranged. As both the control valve armature chamber 42 and the spill valve armature chamber 68 communicate with the return passage 52, which in turn communicates with the vacuum region of the venturi pump 48, a vacuum will be drawn in both armature chambers, as will be described in further detail hereinafter. Additionally, as can be seen in Figure 1, the venturi pump 48 also communicates, by way of the return passage 52, with the groove 27 in the plunger member 26 within which leakage fuel from the pump chamber 20 collects such that a vacuum is also drawn in the groove 27.

[0026] Although not illustrated in the accompanying drawings, the venturi pump 48 may include a venturi pump body defining a flow passage within which a throat member is received, the throat member being shaped to define the throat region of the venturi pump.

[0027] In use, when it is desired to cause pressurisation of fuel within the pump chamber 20, the spill valve member 62 is moved to its seated position (i.e. its closed state) such that reciprocal movement of the plunger member 26 within the plunger bore 24 under the action of the cam arrangement causes fuel within the pump chamber 20 to be pressurised. Fuel under high pressure is therefore delivered to the supply passage 18 and, hence, to the annular chamber 16 and the delivery chamber of the injection nozzle. Fuel under high pressure is also able to flow through the restricted passage 33 into the control chamber 32 at a relatively low rate. If the control valve arrangement 36 is in its closed position, such that communication between the control chamber 32 and the low pressure fuel reservoir is broken, high pressure fuel within the control chamber 32 applies a force to the piston member 34 which serves to urge the valve needle 14 against its seating. Fuel injection does not therefore take place.

[0028] When injection is to be commenced, the control valve arrangement 36 is actuated such that the control valve member 38 is moved to its open position and communication between the control chamber 32 and the low pressure fuel reservoir is opened. Fuel within the control chamber 32 is therefore able to escape to low pressure such that fuel pressure within the control chamber 32 is reduced and, therefore, a reduced force is applied to the piston member 34 and, hence, to the

valve needle 14. A point will be reached when the force due to high pressure fuel within the delivery chamber acting on the valve needle 14 is sufficient to overcome the reduced force which acts on the valve needle 14 due to reduced fuel pressure within the control chamber 32 such that the valve needle 14 is urged away from its seating. When the valve needle 14 is lifted away from the valve needle seating, fuel within the delivery chamber is able to flow past the valve needle seating and into the engine cylinder or other combustion space. It will therefore be appreciated that the timing of injection of fuel delivery by the injector can be controlled by means of the control valve arrangement 36, and the timing of pressurisation of fuel within the pump chamber 20 can be controlled by means of the spill valve arrangement 60.

[0029] On terminating injection at the end of an injection cycle, the spill valve member 62 may be moved out of engagement with the spill valve seating 65a such that the pump chamber 20 is able to communicate, via the drilling 67, with the low pressure fuel reservoir, thereby causing fuel pressure within the pump chamber 20 to be reduced. At about the same time as the spill valve member 62 is moved to its open position, and preferably just before, the control valve arrangement 36 is closed. This has the result that the forces acting on the valve needle 14 urging the valve needle 14 away from the valve needle seating are reduced rapidly, assisting the increased fuel pressure within the control chamber 32 due to closure of the control valve arrangement 36 and giving rise to a rapid termination of injection. This is particularly advantageous where a main injection is to be terminated.

[0030] When the spill valve member 62 is moved into its open position, such that fuel is drawn into the pump chamber 20 through the spill/fill passage 28 and is displaced through the spill/fill passage 28 to the low pressure fuel reservoir as the plunger member 26 reciprocates within the plunger bore 24, fuel will flow into the inlet region 48a of the venturi pump, through the throat region 48c and through the outlet region 48b to the backleak passage 46 and, hence, to the low pressure fuel reservoir. As the diameter of the throat region 48c is smaller than the diameter of the spill/fill passage 28, the velocity of fuel flowing through the throat region 48c is greater than that within the spill/fill passage 28. The increased velocity of fuel flowing through the throat region 48c results in fuel pressure within the throat region 48c being reduced, thereby drawing fuel from the return passage 52 through the restricted drilling 50 into the backleak passage 46 to low pressure.

[0031] Due to the provision of the branch passage 56 providing communication between the control valve armature chamber 42 and the return passage 52, a vacuum is drawn in the chamber 42. A vacuum will also be drawn in the spill valve armature chamber 68. The drawing of a vacuum in both the control valve armature chamber 42 and the spill valve armature chamber 68 provides

the advantage that any pressure waves which may otherwise be generated therein may be substantially eliminated such that unwanted movement of the control valve member 38 and the spill valve member 62 can be avoided. The replacement of fuel escaping from the spill/fill passage 28, through the venturi pump 48 and through the backleak passage 46 to the low pressure fuel reservoir with cooler fuel which is subsequently supplied to the pump chamber 20 also provides an advantage as it facilitates cooling.

[0032] A vacuum is also drawn in the groove or recess 27 provided on the plunger member 26 as the groove 27 also communicates, via the return passage 52, with the throat region 48c of the venturi pump 48. The connection of the venturi pump 48 to the leak collection groove 27 provides the additional advantage that the exchange of engine oils and fuel is minimised.

[0033] It will be appreciated that an advantage is still provided if the throat region 48c of the venturi pump 48 communicates with only one of the armature chambers. Thus, in an alternative embodiment of the invention, the return passage 52 may be arranged to communicate only with the spill valve armature chamber 64, or only with the control valve armature chamber 42, to prevent unwanted vibration of one or the other of the spill valve member 62 or the control valve member 38. Preferably, however, the return passage 52 is arranged to communicate with at least the control valve armature chamber 42 to prevent unwanted movement of the control valve member 38.

Claims

1. A fuel injector comprising a valve needle (14) which is slidable within a bore (12) and engageable with a valve needle seating to control fuel delivery through an outlet opening, a first supply passage (18) for delivering fuel under high pressure to the bore from a pump chamber (20), the valve needle (14) having a surface associated therewith which is exposed to fuel pressure within a control chamber (32), a control valve arrangement (36) for controlling fuel pressure within the control chamber so as to control movement of the valve needle (14) relative to the valve needle seating, a spill/fill passage (28) through which fuel at relatively low pressure is delivered to the pump chamber (20) under the control of a spill valve arrangement (60), wherein the spill/fill passage (28) is provided with a venturi pump (48) in communication with a backleak passage (46) through which fuel flows to a low pressure fuel reservoir.
2. A fuel injector as claimed in Claim 1, wherein the venturi pump (48) includes an inlet region (48a) in communication with the spill/fill passage (28), an outlet region (48b) in communication with the back-

leak passage (46) and a throat region (48c) intermediate the inlet and outlet regions.

3. A fuel injector as claimed in Claim 2, wherein the throat region (48c) of the venturi pump is provided with a feed port (48d) in communication with a return passage (52), such that a vacuum is drawn within the return passage (52) when fuel flows through the throat region (48c).
4. A fuel injector as claimed in Claim 3, wherein a region of the throat region (48c) immediately downstream of the feed port (48d) is of greater cross-sectional area than a further region of the throat region (48c) immediately upstream of the feed port (48d).
5. A fuel injector as claimed in Claim 3 or Claim 4, wherein the spill valve arrangement (60) includes a first armature (64) which is coupled to the spill valve member (62), the first armature (64) being arranged within a first armature chamber (68) and the return passage (52) being arranged to communicate with the first armature chamber (68) such that a vacuum is drawn in the first armature chamber (68).
6. A fuel injector as claimed in any of Claims 3 to 5, wherein the control valve arrangement (36) includes a second armature (40) which is coupled to the control valve member (38), the second armature (40) being arranged within a second armature chamber (42) and the return passage (52) being arranged to communicate with the second armature chamber (42) such that a vacuum is drawn in the second armature chamber (42).
7. A fuel injector as claimed in Claim 5 or Claim 6, wherein at least one of the control valve arrangement (36) and the spill valve arrangement (60) is actuable by means of an electromagnetic actuator.
8. A fuel injector as claimed in any of Claims 3 to 7, further comprising a plunger member (26) which is reciprocal within a plunger bore (24) to pressurise fuel within the pump chamber (20), the return passage (52) being arranged to communicate with a leak collection chamber associated with the plunger member (26), within which leakage fuel from the pump chamber (20) collects, such that a vacuum is drawn in said leak collection chamber.
9. A fuel injector as claimed in Claim 8, wherein the leak collection chamber is defined by a groove or recess (27) provided on the surface of the plunger member (26).
10. A fuel injector as claimed in Claim 8, wherein the leak collection chamber is defined by a groove or recess (27) provided in the plunger bore (24).
11. A fuel injector as claimed in any of Claims 1 to 10, wherein the valve needle (14) is coupled to a piston member (34), a surface of the piston member (34) being exposed to fuel pressure within the control chamber (32).

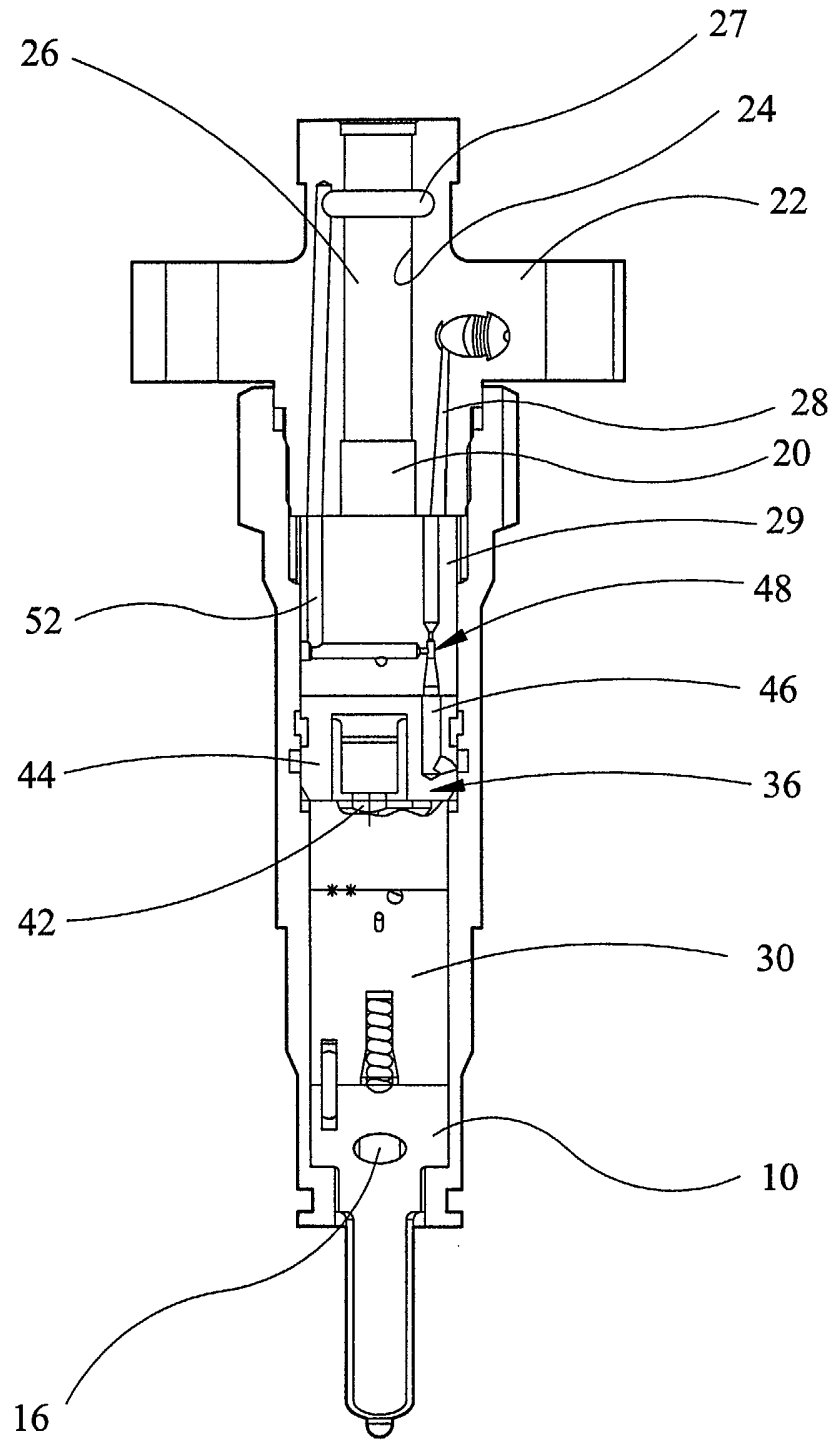


FIG 1

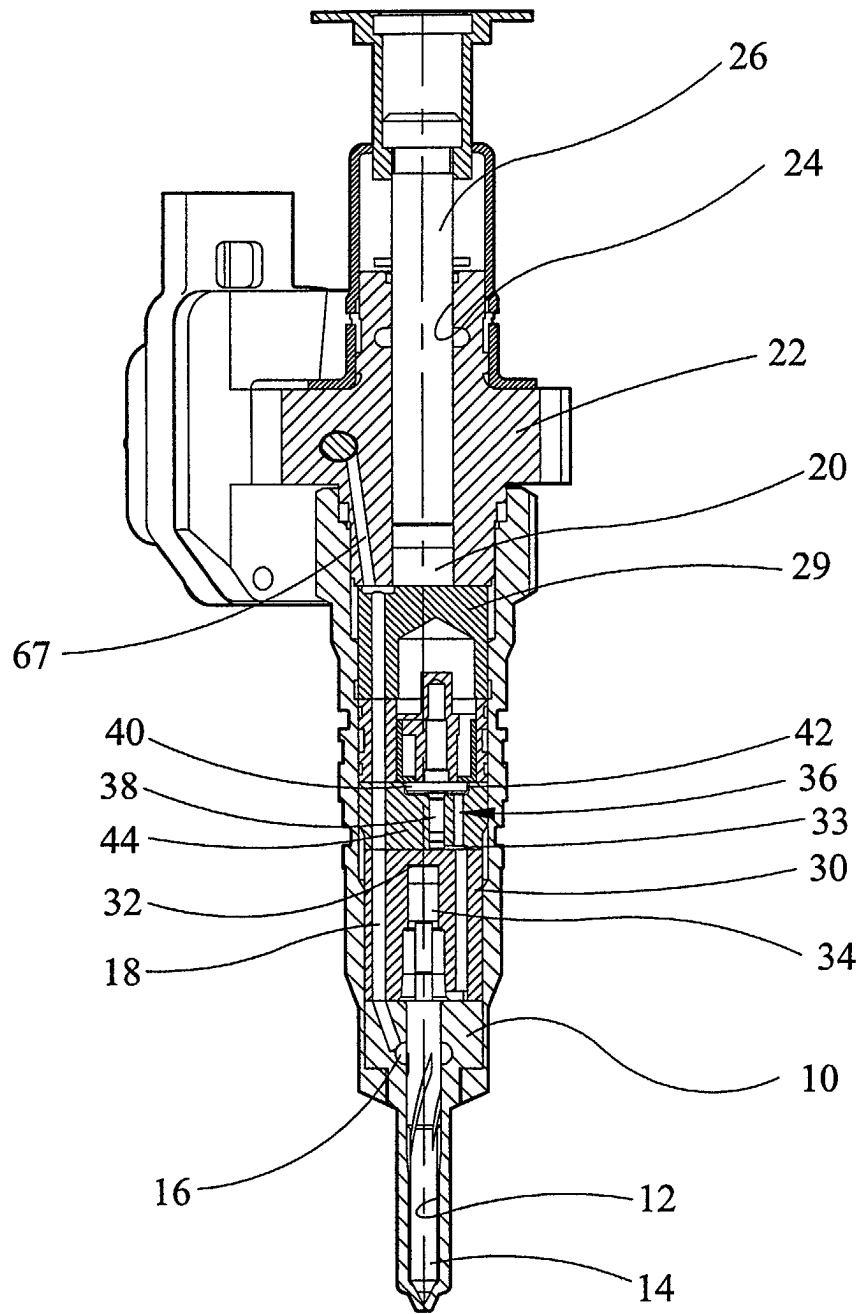


FIG 2

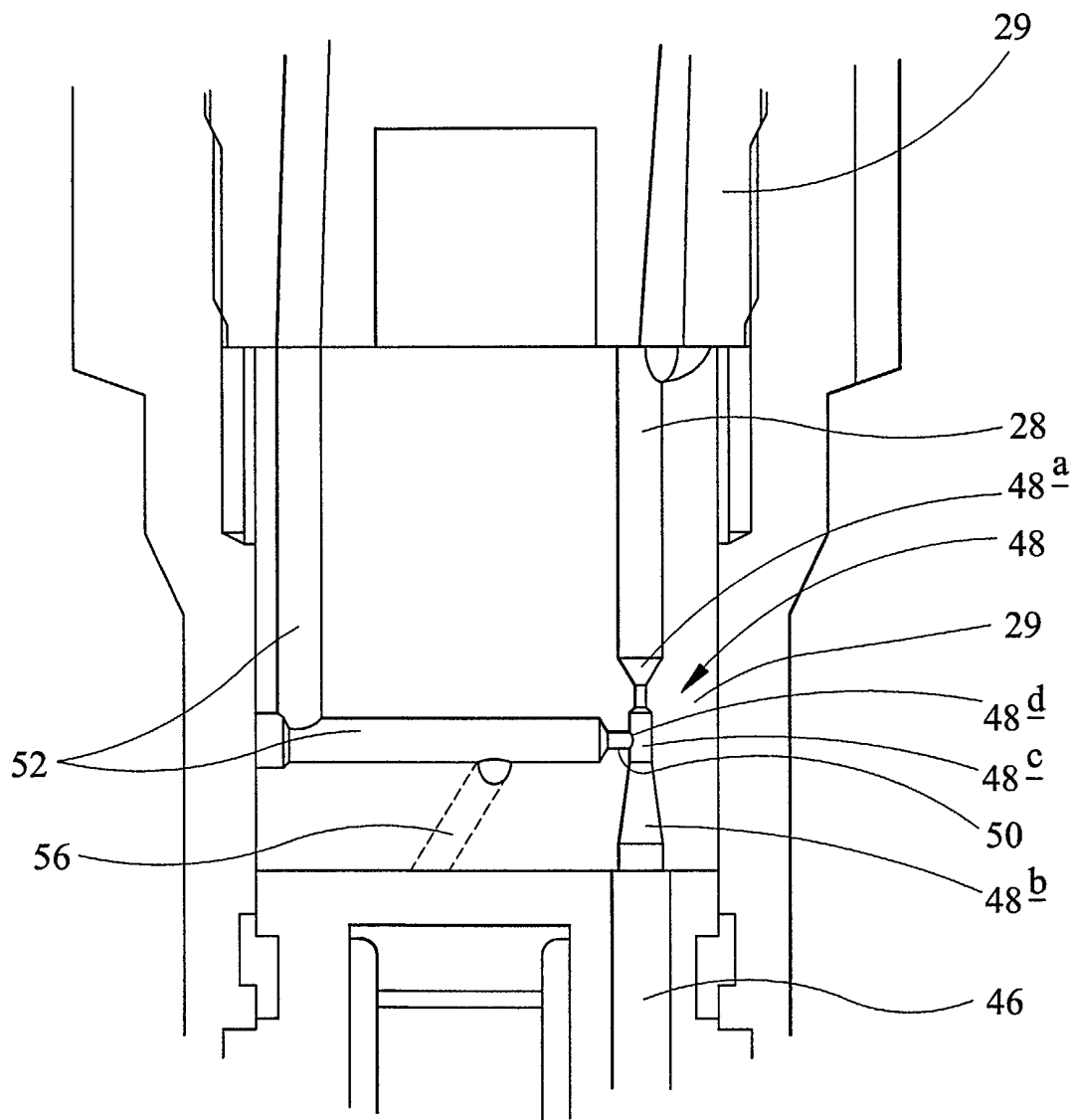


FIG 3

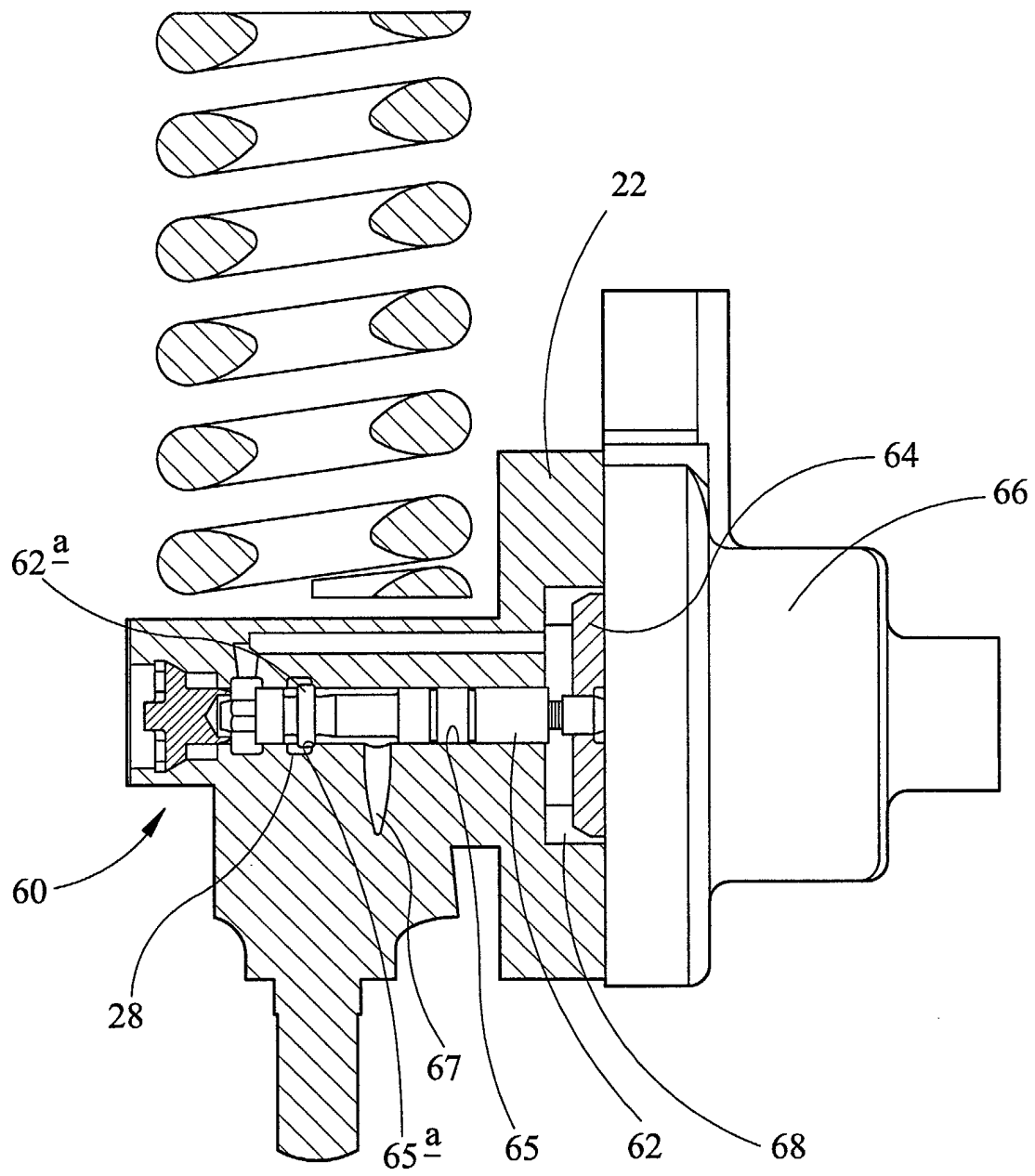


FIG 4



European Patent
Office

EUROPEAN SEARCH REPORT

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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 03/02 (P04001)

**ANNEX TO THE EUROPEAN SEARCH REPORT
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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
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