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(54) Fuel injector

(57) A fuel injector for an internal combustion engine includes a valve needle (14) having a first surface which is engageable with a valve needle seating to control fuel flow between a delivery chamber (20) and an outlet and a high pressure supply passage (22) for supplying fuel at high pressure to the delivery chamber (20). A thrust surface of the valve needle (14) is exposed to fuel pressure within the delivery chamber (20) such that a force is applied to the valve needle (14) to urge the needle away from the valve seating. The injector also includes a pressure chamber (32) in communication with the high pressure supply passage (22) which is defined, in part, by a surface associated with the valve needle (14) at an end thereof remote from the outlet, and means (34, 40; 22, 56, 48, 54) for generating a variable difference in fuel pressure between the delivery chamber (20) and the pressure chamber (32) in dependence upon the rate of increase of fuel pressure within the high pressure supply passage (22), thereby to provide a variable nozzle opening pressure at which the valve needle is caused to lift from the valve needle seating to initiate injection.

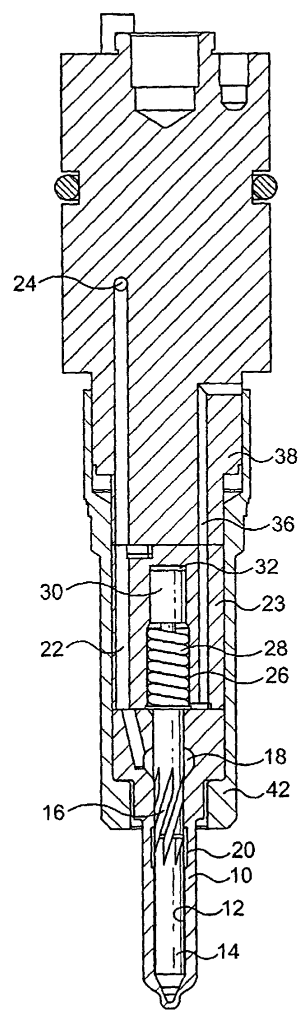

FIG. 1

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Description

[0001] The invention relates to a fuel injector for use in delivering fuel to a combustion space of an internal combustion engine. In particular, but not exclusively, the invention relates to a unit injector for an internal combustion engine or to an injector for use with a unit pump for an internal combustion engine.

[0002] In known unit injectors a pumping element is operable to pressurise fuel within a pumping chamber to a high level, and delivers fuel to an associated injector delivery chamber. The injector is arranged within a common housing with the pump components and a high pressure fuel line defined within the common housing provides a communication path between the pumping chamber and the injector delivery chamber. The injector includes a valve needle which is slidable within a bore provided in a nozzle body housing and engageable with a valve needle seating to control fuel delivery, through one or more injector outlets, to an associated engine cylinder. The valve needle is typically spring biased towards the seating by means of a spring located within a chamber at an end of the valve needle remote from the outlet. In unit pump schemes, the pump elements are usually remotely spaced from the injector components and a separate high pressure fuel line connects a pump outlet to an injector inlet. Such arrangements may also be referred to as "unit pump/injector" arrangements.

[0003] In both unit injector and unit pump schemes the pumping element takes the form of a pumping plunger which is reciprocable within a plunger bore under the influence of a drive arrangement to pressurise fuel within the pumping chamber. A spill valve is operable to open and close communication between the pumping chamber and a low pressure drain. When the spill valve is open, reciprocal movement of the pumping plunger within the bore will cause fuel to be drawn into and displaced from the pumping chamber to the low pressure drain. When the spill valve is closed, communication between the pumping chamber and the low pressure drain is broken so that reciprocal movement of the plunger causes fuel pressure within the pumping chamber to increase.

[0004] A point will be reached during pumping at which the hydraulic forces acting on thrust surfaces of the valve needle due to the supply of high fuel pressure to the delivery chamber are sufficient to overcome the force of the spring, and the valve needle is caused to lift from its seating to commence injection. The pressure at which the injector is caused to lift from its seating is commonly referred to as the "nozzle opening pressure". If the spill valve is opened, fuel within the pumping chamber is displaced to drain as plunger movement continues and the valve needle is returned to its seated position, by means of the spring force, to terminate injection. The spring pre-load determines the pressure at which valve needle opening occurs, and this is typically set by means of a shim located between an end of the valve needle remote from injector outlet and the spring.

[0005] For some applications it is desirable for the injector to have a variable nozzle opening pressure. In particular, it is desirable for the nozzle opening pressure to be relatively high for mid-engine speeds, and lower at rated (maximum) engine speed. It is known to achieve a variable nozzle opening pressure by providing the injector with an electronically controlled injection control valve for actuating valve needle movement, but such systems are relatively complex and costly.

[0006] It is an object of the invention to provide a fuel injector which enables a variable nozzle opening pressure to be achieved at reduced cost.

[0007] According to a first aspect of the present invention, there is provided a fuel injector for an internal combustion engine, the injector comprising:

a valve needle having a surface which is engageable with a valve needle seating to control fuel flow between a delivery chamber and an outlet,

a high pressure supply passage for supplying fuel at high pressure to the delivery chamber, wherein a thrust surface of the valve needle is exposed to fuel pressure within the delivery chamber such tat a force is applied to the valve needle to urge the needle away from the valve seating,

a pressure chamber in communication with the high pressure supply passage which is defined, in part, by a surface associated with the valve needle at an end thereof remote from the outlet, and

means for generating a variable difference in fuel pressure between the delivery chamber and the pressure chamber in dependence upon the rate of increase of fuel pressure within the high pressure supply passage, thereby to provide a variation in nozzle opening pressure at which the valve needle is caused to lift from the valve needle seating to initiate injection.

[0008] The injector may form part of a fuel system including a pump having a pumping plunger which is operable to pressurise fuel within a pumping chamber from where fuel is supplied to the delivery chamber of the injector. The pump has an associated spill valve to control communication between the pump chamber and a low pressure drain. When the spill valve is open, movement of the pumping plunger causes fuel to be drawn into and displaced from the pumping chamber, and when the spill valve is closed fuel is unable to escape to the low pressure drain such that fuel within the pumping chamber is pressurised and a pressure wave is delivered to the high pressure supply passage.

[0009] It is a requirement to increase the fuel pressure at which injection commences (nozzle opening pressure) at mid-engine speeds, but to maintain a relatively lower nozzle opening pressure at maximum, rated speed. At lower engine speeds, there is a relatively low rate of increase of fuel pressure within the high pressure supply passage when the spill valve is closed, so that the pressure difference between the delivery chamber and the pressure chamber is relatively low. This gives rise to a relatively high nozzle opening pressure. For higher engine speeds, there is a higher rate of increase of fuel pressure so that the pressure difference between the delivery chamber and the pressure chamber is increased, thereby giving rise to a reduced nozzle opening pressure. The injector provides this advantageous characteristic with reduced cost and complexity compared with known electronically controlled injectors.

[0010] In a preferred embodiment, the injector includes a piston associated with the valve needle, wherein a surface of the piston defines the pressure chamber.

[0011] Preferably, the injector includes a spring for urging the valve needle towards the valve needle seating. In one embodiment, the spring is housed within a spring chamber and is preferably engaged between a first surface associated with the valve needle and a shim located within the spring chamber. Appropriate selection of the shim enables the spring pre-load to be set to a desired amount.

[0012] Alternatively, the spring may be engaged between a first surface associated with the valve needle and a surface of the spring chamber.

[0013] Preferably, the piston acts on the valve needle through a push rod which extends through the spring,

[0014] In an alternative embodiment of the invention, a surface of the valve needle defines the pressure chamber.

[0015] In one embodiment of the invention, the injector includes a first restricted flow path for fuel between the high pressure supply passage and the pressure chamber to permit a continuous flow of high pressure fuel into the pressure chamber at a restricted rate, and a second restricted flow path between the pressure chamber and a low pressure drain to permit a continuous flow of fuel to the low pressure drain at a restricted rate.

[0016] Preferably the first restricted flow path is arranged adjacent to the second restricted flow path in a common housing part.

[0017] In an alternative embodiment of the invention, the injector includes a first flow path between an injector inlet and the delivery chamber, and a second flow path between the injector inlet and the pressure chamber, wherein the first and second flow paths have different flow lengths.

[0018] The high pressure supply passage is preferably defined by a first drilling provided in a further injector housing. Preferably, both the first flow path and the second flow path are defined, in part, by a common region of the high pressure supply passage, and the second flow path is further defined by a second drilling defined, at least in part, within said further injector housing.

[0019] The second drilling preferably communicates with the first drilling through a branch passage defined by a recess provided in an upper surface of an injector housing.

[0020] Preferably, the high pressure supply passage is provided with a restriction to reduce the pressure of fuel acting on a thrust surface of the valve needle during injection to a level below that prior to injection.

[0021] According to a second aspect of the present invention, there is provided a fuel pump, comprising:

a pumping plunger which is operable to pressurise fuel within a pumping chamber,

a spill valve for controlling communication between the pumping chamber and a low pressure drain,

an injector having a delivery chamber to which fuel is supplied, in use, from the pumping chamber though a high pressure supply passage,

a valve needle having a first surface which is engageable with a valve needle seating to control fuel flow between the delivery chamber and an injector outlet, wherein a thrust surface of the valve needle is exposed to fuel pressure within the delivery chamber such that a force is applied to the valve needle to urge the needle away from the valve seating,

a pressure chamber in communication with the high pressure supply passage which is defined, in part, by a surface associated with the valve needle at an end thereof remote from the injector outlet, and

means for generating a variable difference in fuel pressure between the delivery chamber and the pressure chamber in dependence upon the rate of increase of fuel pressure within the high pressure supply passage, thereby to provide a variable nozzle opening pressure at which the valve needle is caused to lift from the valve needle seating to initiate injection.

[0022] The fuel pump typically takes the form of a so-called "unit injector" in which the pumping plunger and the injector are arranged within a common unit.

[0023] It will be appreciated that the preferred and/or optional features of the first aspect of the invention, for example as set out in the accompanying dependent claims, may also be included in the fuel pump of the second aspect of the invention.

[0024] The invention will now be described, by way of example only, with reference to the accompanying drawings in which:

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

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

Figures 3 to 5 are sectional views of an alternative embodiment of the injector to that shown in Figures 1 and 2.

[0025] Referring to Figures 1 and 2, an injector in accordance with a first embodiment of the invention includes a nozzle body 10 provided with a blind bore 12 within which a valve needle 14 is slidable. The valve needle 14 is engageable with a valve needle seating (not identified) to control fuel delivery through one or more injector outlets (not shown) into an associated engine cylinder or other combustion space. The valve needle 14 is provided with a plurality of flats, slots or grooves 16 on its outer surface which permit fuel to flow from an annular chamber 18 defined by an enlarged region of the bore 12 to a delivery chamber 20 defined by a downstream region of the bore 12. The valve needle 14 also includes one or more thrust surfaces (not shown) exposed to fuel pressure within the delivery chamber 20 such that a force due to fuel pressure acting on the thrust surface serves to urge the valve needle 14 away from the valve needle seating.

[0026] The annular chamber 18 receives fuel at high pressure through a high pressure supply passage 22 defined by a plurality of drillings provided in various injector housing parts. The high pressure supply passage 22 communicates with an injector inlet 24 which receives pressurised fuel from a fuel pump (not shown). Typically, the pump is of the type including a pumping plunger which is driven to pressurise fuel within a pumping chamber. A spill valve of the pump is operable to control communication between the pumping chamber and a low pressure drain so that when the spill valve is open, movement of the pumping plunger causes fuel to be drawn into and displaced from the pumping chamber, and when the spill valve is closed fuel is unable to escape to the low pressure drain such that fuel within the pump chamber is pressurised to a high level as the pumping plunger performs a pumping stroke. High pressure fuel is typically delivered from the pumping chamber to the inlet 24 of the injector under the control of a delivery valve.

[0027] An upper surface of the nozzle body 10 abuts a first injector housing part 23 provided with a stepped blind bore, a lower portion of which defines a spring chamber 26 housing a compression spring 28. One end of the spring 28 acts on an upper surface of the valve needle 14 and the other end of the spring 28 engages the step in the bore within the chamber 26, such that the spring 28 urges the valve needle 14 towards the valve needle seating. The piston 30 is slidable within the bore in the injector housing 23 and is coupled to the valve needle 14 through a push rod (not visible in the view shown) which extends through the spring 28. As can be seen most clearly in Figure 2, an upper surface of the piston 30 defines, together with the blind end of the bore in the injector housing 23, a pressure chamber 32 which communicates continuously with a portion of the high pressure supply passage 22 through a first restriction 34 defined by a drilling in the injector housing 23.

[0028] A low pressure drain passage 36 provides a return flow path for leakage fuel in the spring chamber 26 to low pressure, the low pressure drain passage 36 being defined partially within the first injector housing 23 and partially within a second injector housing 38 in abutment with the first injector housing 23. The pressure chamber 32 communicates with the low pressure drain passage 36 through a second restriction 40 defined by an additional drilling in the first injector housing part 23, in a position generally adjacent to the first restriction 34. The second restriction 40 permits a continuous flow of fuel from the pressure chamber 32 to low pressure at a restricted rate. The first restriction 34 permits fuel to flow from the high pressure flow passage 22 into the pressure chamber 32 at a restricted rate, fuel delivered to the pressure chamber 32 also being able to flow continuously from the pressure chamber 32 to the low pressure passage 36 at restricted rate through the second restriction 40, as shown in Figure 2. The first and second restrictions 34, 40 respectively may be shaped to enable similar or the same rates of fuel flow therethrough, or different flow rates.

[0029] The first and second housing parts 23, 38 and the upper end of the nozzle body 10 are received within a cap nut 42 in a conventional manner. If the injector takes the form of a so-called "unit injector", the pumping plunger and associated pump components of the pump for supplying high pressure fuel to the delivery chamber 20 are arranged within a common housing.

[0030] In use, when the spill valve of the pump is closed to cause pressurisation of fuel within the pumping chamber, high pressure fuel delivered to the inlet 24 of the injector flows through the supply passage 22 and, hence, is delivered both to the annular chamber 18 and through the first restriction 34 to the pressure chamber 32. Fuel delivered to the pressure chamber 32 is able to flow, at a restricted rate, through the second restriction 40 and to the low pressure passage 36. Fuel delivered to the annular chamber 18 is able to flow past the flats 16 on the surface of the valve needle 14 into the delivery chamber 20.

[0031] A point will be reached at which the force acting on the valve needle thrust surface due to fuel pressure within the delivery chamber 20 is sufficient to overcome the combined force of the spring 28 and the force due to fuel pressure within the pressure chamber 32 acting on the piston 30, and the valve needle 14 is caused to lift away from the valve needle seating to commence injection.

[0032] It will be appreciated from the geometry of the arrangement shown in Figure 1 that the pressure wave through the high pressure supply passage 22 will reach the pressure chamber 32 slightly in advance of the annular chamber 18. However, due to the provision of the first and second restrictions 34, 40 restricting the flow rate into and out of the pressure chamber 32, the magnitude of the pressure wave at the pressure chamber 32 will be slightly less than that at the annular chamber 18. The rate of increase in fuel pressure within the pressure chamber 32 is therefore less than the rate of increase in fuel pressure within the delivery chamber 20, thereby creating a pressure difference between the pressure chamber 32 and the delivery chamber 20. The nozzle opening pressure at which the valve needle 14 is caused to lift from the valve needle seating to initiate injection is determined by the force due to fuel pressure within the delivery chamber 20 acting on the surface area of the thrust surface of the valve needle, the pre-load of the spring 28 and the force due to fuel pressure within the pressure chamber 32 acting on the surface area of the piston 30. The pressure difference between the pressure chamber 32 and the delivery chamber 20 therefore influences the nozzle opening pressure and, as the characteristics of the pressure wave through the high pressure supply passage 22 are dependent upon pumping speed (as determined by engine speed), this pressure difference, and hence the nozzle opening pressure, will vary with engine speed.

[0033] When it is desired to terminate injection, the spill valve of the pump is open such that further plunger movement simply draws fuel into and displaces fuel out of the pumping chamber, and the pressure of fuel delivered to the high pressure supply passage 22 is reduced. When fuel pressure within the delivery chamber 20 is reduced below the predetermined amount at which the upward force acting on the valve needle thrust surface is overcome by the force of the spring 28 acting in combination with fuel pressure within the pressure chamber 32, the valve needle 14 is urged against the valve needle seating to terminate injection.

[0034] In an alternative embodiment to that described previously, the piston 30 may be coupled to the valve needle 14 directly, in which case the push rod is integrally formed with the piston 30. In this embodiment, it is effectively a surface of the valve needle which is exposed to fuel pressure within the pressure chamber 32.

[0035] Figures 3 to 5 illustrate three sectional views of a further alternative embodiment of the invention. As can be seen in the view shown in Figure 4, a lower surface of the piston 30 abuts one end of a push rod 41, the other end of which is coupled to the valve needle 14 through a load transmitting member 43. The load transmitting member 43 defines a seat for one end of the spring 28, the other end of the spring 28 being engaged with a shim 44 located at an upper end of the spring chamber 26. The shim 44 is selected to provide the desired spring pre-load which, in turn, influences the nozzle opening pressure, as described in further detail below.

[0036] The injector in Figures 3 to 5 differs from that in Figure 1 in that the force acting on the valve needle 14 to urge the needle away from the seating acts on a thrust surface exposed to fuel pressure within the annular chamber 18, and the flats 16 and the delivery chamber 20 in the nozzle of Figure 1 are omitted. Movement of the valve needle 14 in the embodiment shown in Figures 3 to 5 is effected in the same way, however, and occurs when fuel pressure within the annular chamber 18 is sufficient to overcome the combined force of a spring and fuel pressure acting on the back end of the needle, as described in further detail below.

[0037] The injector in Figures 3 to 5 also differs from that in Figures 1 and 2 in that the upper end of the nozzle body 10 abuts a first face of an adapter plate 46 through which a portion of the high pressure supply passage 22 extends, the opposing face of the adapter plate 46 being in abutment with the second injector housing 38. The second injector housing 38, the adapter plate 46 and the upper end region of the nozzle body 10 are received within the cap nut 42 in a conventional manner. The second injector housing 38 and the adapter plate 46 are provided with correspondingly shaped drillings or recesses within which a location pin 47 is received to ensure correct alignment of parts.

[0038] As can be seen in the views shown in Figures 3 and 5, in addition to the high pressure supply passage 22, the second injector housing 38 is also provided with an additional drilling 48, one end of which communicates with the pressure chamber 32 via a cross drilling 54 in the second injector housing 38. The additional drilling 48 communicates with a region of the high pressure supply passage 22 through a branch passage 56 defined by a recess provided in the upper end face of the adapter plate 46. It will therefore be appreciated that a first flow path is defined between the injector inlet 24 and the delivery chamber 20 by the high pressure supply passage 22, and a second flow path is defined between the injector inlet 24 and the pressure chamber 32 by a portion of the high pressure supply passage 22, the branch passage 56, the additional drilling 48 and the cross drilling 54. As can be seen most clearly by comparing Figures 3 and 4, the first and second flow paths have different flow lengths.

[0039] Operation of the injector in Figures 3 to 5 to commence injection is similar to that described previously for the embodiment in Figures 1 and 2. Fuel is delivered to the high pressure supply passage 22 through the injector inlet 24 from the pump, and is able to flow into the annular chamber 18. High pressure fuel within the supply passage 22 is also able to flow into the pressure chamber 32 through the second flow path and applies a downward force to the piston 30, and hence to the valve needle 14 through the push rod 41 and the load transmitting member 43. When fuel pressure within the delivery chamber is increased to an amount which is sufficient to overcome the force due to the spring 28, acting in combination with the force due to high fuel pressure within the pressure chamber 32, the valve needle 14 is urged away from the valve needle seating and injection commences.

[0040] The nozzle opening pressure will be determined by the difference in fuel pressure between the pressure chamber 32 and the delivery chamber 20, and also by the pre-load of the spring 28. Due to the length of the additional drilling 48 through which fuel flows to the pressure chamber 32, and hence the different flow path lengths between the injector inlet 24 and the delivery chamber 20 and between the injector inlet 24 and the pressure chamber 32, the pressure wave transmitted through the high pressure supply passage 22 will reach the delivery chamber 20 in advance of the pressure wave at the pressure chamber 32. For low engine speeds, when the rate of pressure increase is low, this difference in flow path length will have a relatively less significant effect on the pressure difference across the chambers 32, 20 than for higher engine speeds when the rate of pressure increase is higher. For lower engine speeds the nozzle opening pressure is therefore higher than for higher engine speeds. The embodiment of Figures 3 to 5 therefore also provides the advantage that the nozzle opening pressure is variable with engine speed, from a relatively higher nozzle opening pressure at relatively low engine speeds to a relatively lower nozzle opening pressure at higher engine speeds.

[0041] The length of the additional drilling 48 to the pressure chamber 32 may be selected to give the required variable nozzle opening pressure characteristics with engine speed. In an alternative arrangement, the branch passage 56 to the pressure chamber 32 may communicate with the high pressure supply passage 22 further downstream of the point shown in Figures 3 to 5 to create a greater difference in flow path length, For example, the branch passage 56 may be defined by a recess or groove provided in an upper surface of the nozzle body 10.

[0042] In the embodiment of Figures 3 to 5, the high pressure supply passage 22 defines a common region of both the first flow path length between the injector inlet 24 and the delivery chamber 20, and the second flow path length between the injector inlet 24 and the pressure chamber 32. Alternatively, however, the injector may be configured such that two separate high pressure flow passages of differing flow length branch from the injector inlet 24 to the pressure chamber 32 and the delivery chamber 20 respectively.

[0043] As a preferred, optional feature, the supply passage 22 may be provided with a restriction (not shown in the accompanying figures) which results in a reduction in the force acting on the valve needle thrust surface when the valve needle is lifted from its seating. A smaller force is therefore required to seat the valve needle, permitting faster needle closure. Such a feature is described in the applicant's European patent, EP0767304, and results in the pressure acting on the thrust surface during injection being lower than that prior to injection.

[0044] The embodiments of the invention shown in the figures are of the type in which a unit pump is arranged remotely from the injector and delivers fuel from the pumping chamber of the pump to the injector through a separate high pressure flow line. It will be appreciated, however, that the invention is equally applicable to unitary pump/injector schemes in which the injector nozzle body and a pump body are arranged within a common housing in a so-called "close coupled" unit pump/injector arrangement.

Claims

1. A fuel injector for an internal combustion engine, the injector comprising:

    a valve needle (14) having a first surface which is engageable with a valve needle seating to control fuel flow between a delivery chamber (20) and an outlet,

    a high pressure supply passage (22) for supplying fuel at high pressure to the delivery chamber (20), wherein a thrust surface of the valve needle is exposed to fuel pressure within the delivery chamber (20) such that a force is applied to the valve needle (14) to urge the needle away from the valve seating,

    a pressure chamber (32) in communication with the high pressure supply passage (22) which is defined, in part, by a surface associated with the valve needle (14) at an end thereof remote from the outlet, and

    means (34, 40; 22, 56, 48, 54) for generating a variable difference in fuel pressure between the delivery chamber (20) and the pressure chamber (32) in dependence upon the rate of increase of fuel pressure within the high pressure supply passage (22), thereby to provide a variable nozzle opening pressure at which the valve needle (14) is caused to lift from the valve needle seating to initiate injection.

2. A fuel injector as claimed in Claim 1, wherein the injector includes a piston (30) associated with the valve needle (14), wherein a surface of the piston (30) defines the pressure chamber (32).

3. A fuel injector as claimed in Claim 1 or Claim 2, further comprising a spring (28) arranged within a spring chamber (26) for urging the valve needle (14) towards the valve needle seating.

4. A fuel injector as claimed in Claim 3, wherein the

spring (28) is engaged between a first surface associated with the valve needle (14) and a shim (44) located within the spring chamber (26).

5. A fuel injector as claimed in Claim 3 or Claim 4, wherein the piston (30) acts on the valve needle (14) through a push rod (41) extending through the spring (28).

6. A fuel injector as claimed in Claim 1 or Claim 2, wherein a surface of the valve needle (14) defines the pressure chamber (32).

7. A fuel injector as claimed in Claim 6, further comprising a spring (28) arranged within a spring chamber (26) for urging the valve needle (14) towards the valve needle seating.

8. A fuel injector as claimed in any one of Claims 1 to 7, wherein the means for generating a variable fuel pressure difference includes a first restricted flow path (34) for fuel between the high pressure supply passage (22) and the pressure chamber (32) to permit a continuous flow of high pressure fuel into the pressure chamber (32) at a restricted rate, and a second restricted flow path (40) between the pressure chamber (32) and a low pressure drain to permit a continuous flow of fuel out of the pressure chamber (32) to the low pressure drain at a restricted rate.

9. A fuel injector as claimed in Claim 8, wherein the first and second restricted flow paths are defined by first and second drillings (34, 40) respectively formed in an injector housing (23), each drilling having one end in communication with the pressure chamber (32).

10. A fuel injector as claimed in any one of Claims 1 to 7, wherein the injector includes a first flow path (22) between an injector inlet (24) and the delivery chamber (20), and a second flow path (22, 56, 48, 54) between the injector inlet (24) and the pressure chamber (32), wherein the first and second flow paths have different flow lengths.

11. A fuel injector as claimed in Claim 10, wherein the high pressure supply passage (22) is defined by a first drilling provided in a further injector housing (38), both the first flow path and the second flow path being defined, in part, by a common region of the high pressure supply passage (22) and wherein the second flow path is further defined by a second drilling (48) defined, at least in part, within the said further injector housing (38).

12. A fuel injector as claimed in Claim 11, wherein the second drilling communicates with the first drilling through a branch passage (56) defined by a recess provided in an upper surface of an additional injector housing part (46).

13. A fuel injector as claimed in any one of Claims 1 to 12, wherein the valve needle (14) includes a thrust surface to which fuel pressure is applied, in use, to urge the valve needle (14) away from the valve needle seating and wherein the high pressure supply passage (22) is provided with a restriction to reduce the force acting on the thrust surface during injection to a level below that prior to injection.

14. A unit fuel pump comprising:

a pumping plunger which is operable to pressurise fuel within a pumping chamber,

a spill valve for controlling communication between the pumping chamber and a low pressure drain, and

an injector as claimed in any one of Claims 1 to 13.

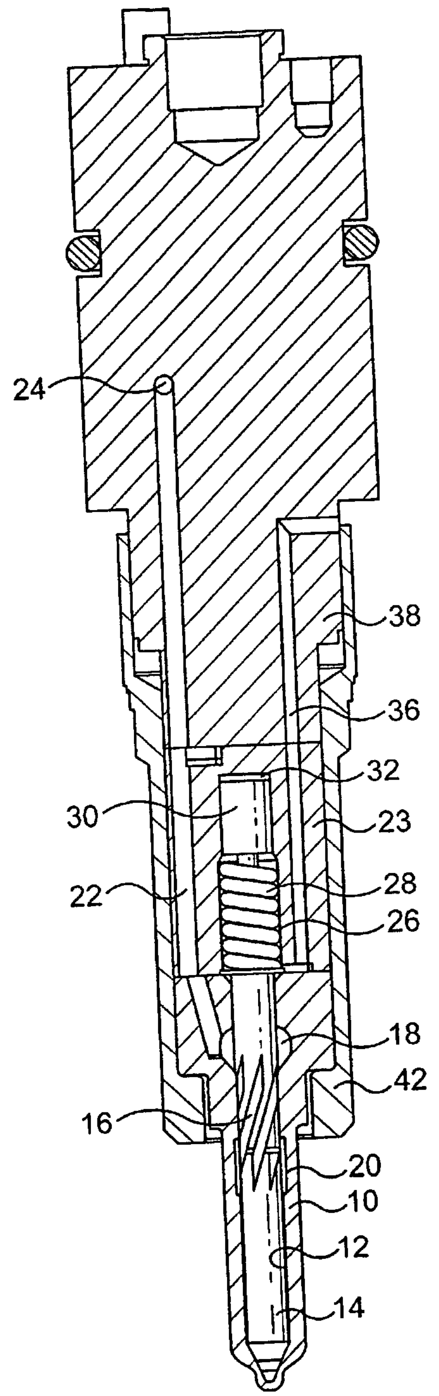

FIG. 1

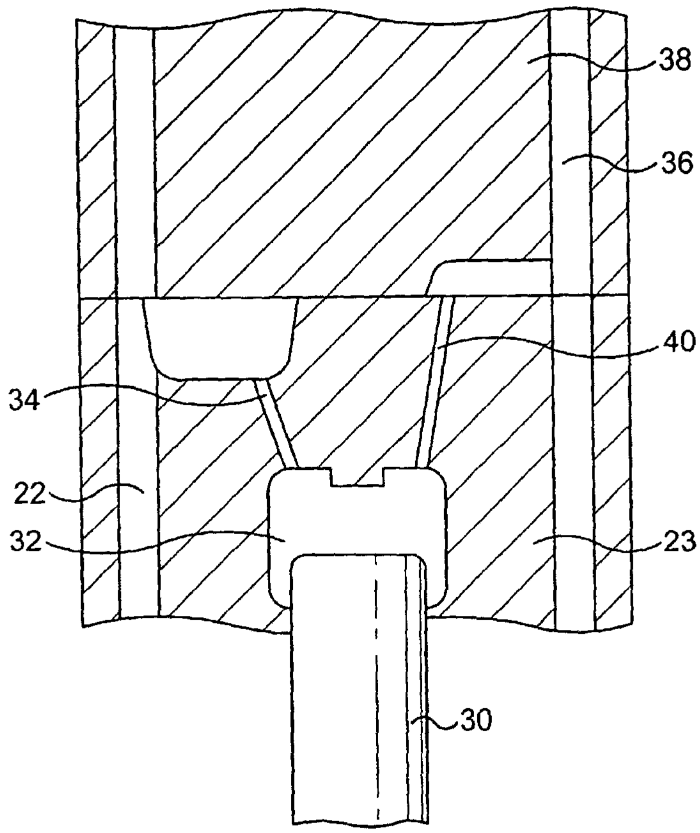

FIG. 2

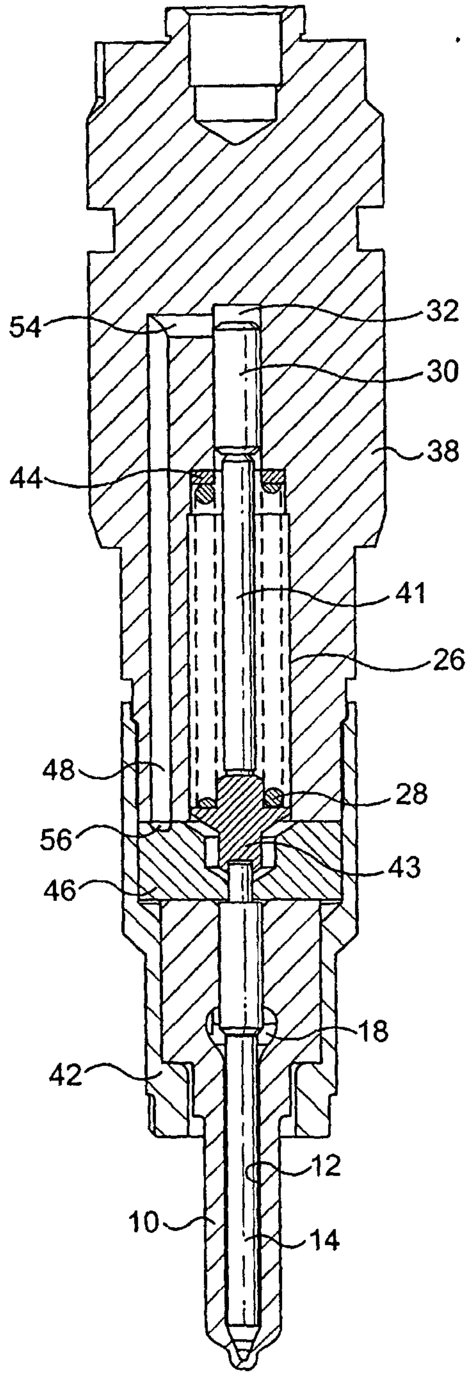

FIG. 3

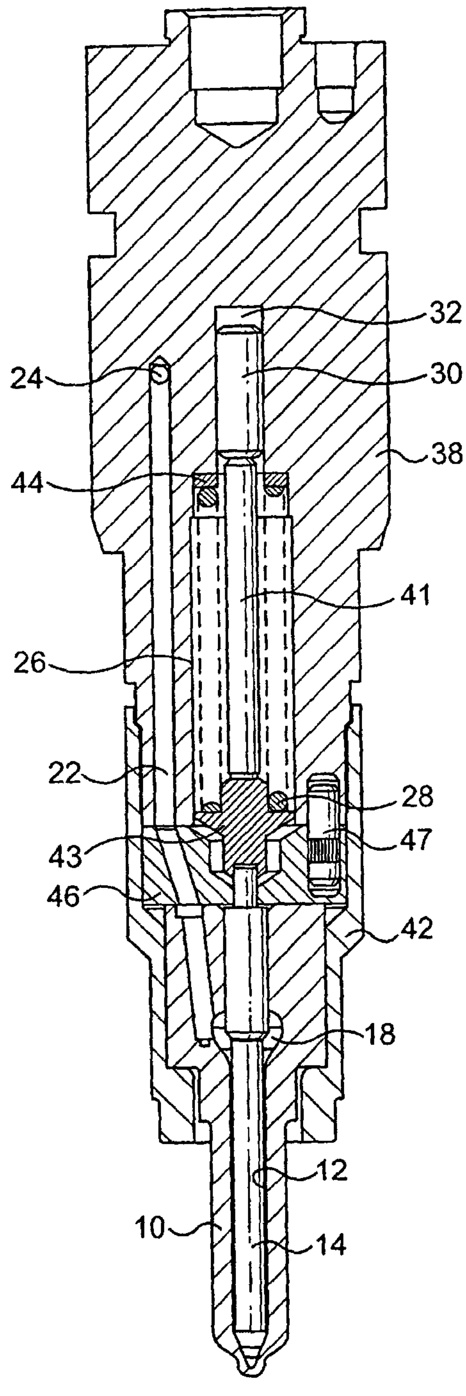

FIG. 4

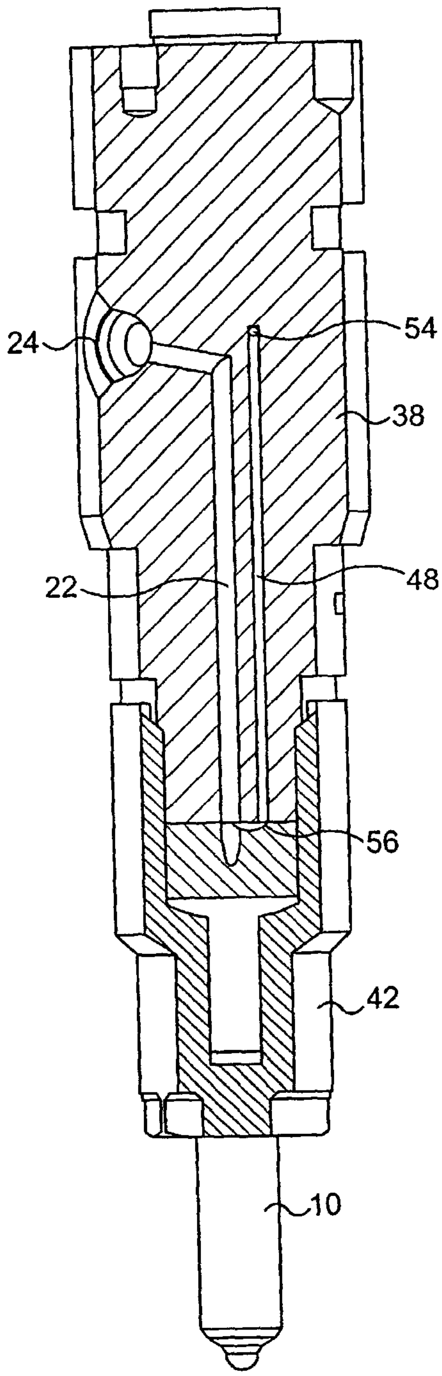

FIG. 5