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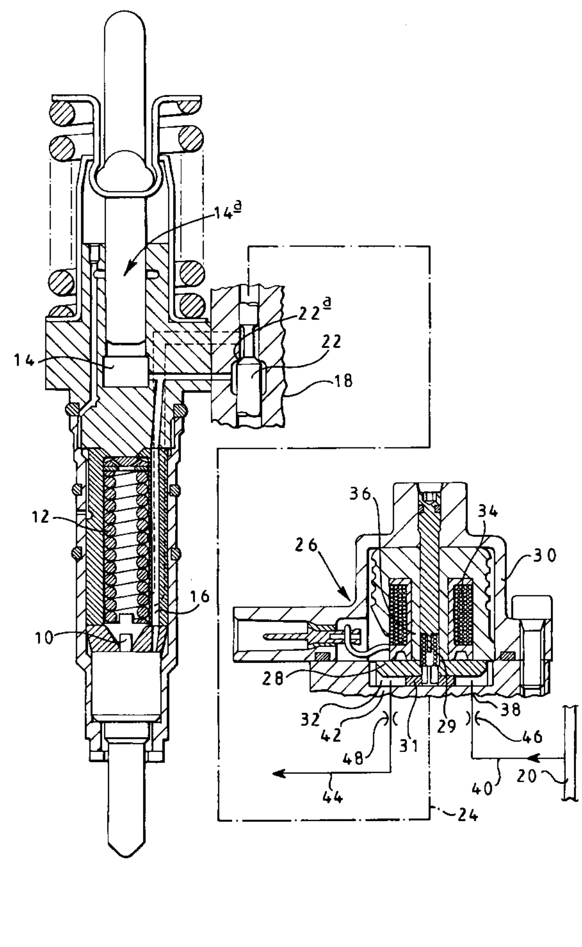
(54) Fuel injector

(57) A fuel injector incorporating an electromagnetically operated spill valve is disclosed. The armature (28) of the electromagnet is moveable within an armature chamber (32) through which fuel flows in use. The injector further comprises means controlling the flow of fuel through said chamber so that the pressure of fuel within said chamber (32) is such that at least one of the opening and closing bounce of the armature and associated spill valve is mitigated.



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Description

[0001] This invention relates to a fuel injector for supplying fuel to a cylinder of an internal combustion engine, particularly an electronic unit injector (EUI) which incorporates an electromagnetically operated spill valve operation of which is controlled electronically to control the delivery of fuel to the cylinder.

[0002] Conventionally an EUI incorporates a pumping mechanism which is supplied with fuel at a relatively low pressure (feed pressure) from a feed rail of the injection system, the pump greatly increasing the fuel pressure for injection purposes. Opening and closing of the spill valve controls operation of the injector by controlling the application to the injector of the pressure generated by the pump. Fuel under pressure dumped when the spill valve opens is returned to the feed rail. Fuel leaking internally within the injector in use is returned via a drain line to the fuel reservoir.

[0003] The moveable valve member of the spill valve is moved against the action of a return spring by an armature of an electromagnet, the armature being moved within an armature chamber of the electromagnet housing by energization of the electromagnet. It is known to effect either closing, or opening, of the spill valve as a result of energization of the electromagnet. Both ends of the range of movement of the moveable valve member of the spill valve are determined by mechanical stops and it is recognised that rapid movement, followed by rapid arrest, of the valve member can result in an undesirable bounce of the valve member of the spill valve. Thus either the spill valve may bounce when closing to give a transient second opening prior to full closure, or upon opening may bounce to give a transient second partial closure before full opening. Bouncing of the spill valve at the ends of its operating stroke, notably the closed end, is a known problem giving rise to inefficient, uncontrolled operation of the injector, and the mitigation or obviation of this problem is an object of the present invention.

[0004] Fuel returned to the feed rail from the spill valve is hotter than the fuel in the feed rail and thus raises the fuel rail temperature undesirably. It is known to provide a bypass flow of fuel from the fuel feed rail of the injection system which passes through the electromagnet armature chamber back to the low pressure reservoir, thus continually causing a flow of cool fuel from the reservoir through the feed rail to balance the heating effect of fuel dumped via the spill valve and so stabilize the temperature of the system.

[0005] In accordance with the present invention there is provided a fuel injector incorporating an electromagnetically operated spill valve, the armature of the electromagnet being moveable within an armature chamber through which fuel flows in use, and means controlling the flow of fuel through said chamber so that the pressure of fuel within said chamber is such that at least one of the opening and closing bounce of the armature and associated spill valve is mitigated.

[0006] Preferably said means comprises a first flow restrictor in the fuel inlet to said chamber, and a second flow restrictor in the fuel outlet from said chamber, the values of the restrictions to flow formed by said first and second restrictors being chosen in relation to the system feed and drain pressures and the flow characteristics of the chamber, such that the fuel pressure in the chamber reduces the possibility of armature and associated valve bounce at the open and/or closed limits of the spill valve movement.

[0007] The invention also resides in a method of manufacturing a fuel injector of the kind specified hereinbefore including the steps of selecting armature chamber inlet and outlet flow restrictors to achieve a predetermined fuel pressure within the armature chamber to minimize the possibility of armature/spill valve bounce.

[0008] One example of the invention will now be described in more detail with reference to the accompanying drawing which is a diagrammatic representation of an electronically controlled unit fuel injector.

[0009] Referring to the drawing, the injector includes a needle valve 10 biased into engagement with a seating (not shown) by a spring 12. The injector includes a pumping chamber 14 which receives fuel from a low pressure fuel feed rail 20 and which communicates with the needle valve 10 through a passageway 16 in known manner, whereby fuel under pressure can be applied to the needle 10 to lift the needle 10 from its seating to open the injector. A spill valve 18 incorporated within or mounted upon the injector assembly communicates with the passage 16, and when open, connects the passage 16 to the feed rail 20 to dump high pressure fuel back into the fuel feed rail.

[0010] The feed rail 20 supplying pumping chamber 14 with fuel at relatively low pressure (feed pressure), may be common to all of the injectors of an engine and supplies fuel from the fuel reservoir to the injectors. The pumping mechanism 14a of the injector is mechanically operated, and displaces fuel from the pumping chamber 14 into the passage 16. If the spill valve 18 is open then hot high pressure fuel pumped from the chamber 14 passes back to the rail 20. Closure of the spill valve 18 allows the pump to further pressurize the fuel in the chamber 14 and passage 16, resulting in the fuel pressure applied to the valve needle 10 increasing. At a predetermined pressure in the passage 16 the needle 10 lifts against the action of the spring 12 allowing fuel to be delivered past the seating and into the cylinder of the engine. Opening of the spill valve 18 dumps the pressure in the passage 16 thus permitting the spring 12 to restore the needle 10 to the valve seating terminating fuel injection. The pressure of fuel within the chamber 32 affects the intensity with which the pressure is re-established in the region between the armature plate 28 and the stator of the actuator at the instant after spill valve closure. The higher the chamber pressure, the more vigorous the disturbing force applied to the armature end of the valve, and the larger the bounce. Consequently reducing the armature chamber pressure reduces the magnitude of the bounce, up to a point.

[0011] The operating spool 22 of the spill valve 18 is linked by a pushrod 24 (depicted diagrammatically in the drawing) to an armature plate 28 of an electromagnetic actuator 26. The armature plate 28 is in the form of a rectangular plate moveable transverse to its plane within an armature chamber 32 defined in the casing 30 of the actuator 26. Energization of the winding 34 of the electromagnet moves the armature plate 28 axially to the position illustrated in the drawing wherein it is closely adjacent the E-shaped core 36 of the electromagnet, and the spill valve is closed. De-energization of the winding 34 allows the armature plate 28 to be moved under the action of a valve spool return spring 29 to the opposite end of its travel wherein a stop means in the form of a shim 31 abuts the casing 30, and the spill valve is open.

[0012] The armature chamber 32 is formed, adjacent one edge with a fuel inlet 38 which is connected through a line 40 to the feed rail 20, and a fuel outlet 42 generally opposite the inlet 38. The outlet 42 communicates with the fuel reservoir by way of a drain line 44 connecting the outlet 42 to the fuel drain.

[0013] The feed rail pressure is significantly in excess of the drain line pressure and thus fuel flows continually in a bypass path including the chamber 32 drawing cool fuel from the reservoir into the rail to balance the heating effect of hot fuel dumped into the rail by the spill valve.

[0014] The chamber 32 is thus continually full of fuel at a pressure between feed pressure and drain pressure. A gap between the wall of the chamber 32 and the periphery of the armature plate 28 permits fuel to flow around the armature plate 28 as the armature plate moves within the chamber 32 in use. However, it has now been determined that the pressure of the fuel within the chamber 32 is of significance in relation to minimizing bounce of the plate 28, and thus the spool 22 of the spill valve at the ends of their travel.

[0015] It will be recognised that the spill valve depicted in the drawing is most critical to bounce at its closed position since there is a degree of latitude in the fully open position of the spill valve. It can be seen that the spool 22, in the closed position engages a seating 22a in the spill valve body fractionally in advance of the plate 32 engaging the core 36, and bounce from this closed position, as the closed position is achieved, will give a momentary second opening of the spill valve with disadvantageous effects on the fuel delivery characteristic of the injector. It must be recognised that the drawing is highly diagrammatic and in practice there is a direct link between the plate 28 and the valve spool 22.

[0016] It has been determined that for a given design and application of the injector and a given design of spill valve/electromagnet, certain pressure conditions within the chamber 32 will minimize armature/spill valve bounce. The relevant pressure will dependent *inter alia* upon the application, and the design of the plate 28 and chamber 32, but can be determined by experiment.

[0017] Once the desired pressure within the chamber 32 has been determined it can be achieved, by selecting appropriately sized flow restrictors 46 and 48 in the lines 40 and 44 respectively to provide, on the basis of the pressure difference between the feed line 20 and fuel drain, the desired flow rate of fuel through the chamber 32 for appropriate cooling, while at the same time maintaining the optimum pressure in the chamber 32 to minimize armature plate, and therefore valve spool, bounce.

[0018] In one example the fuel has a density of 760 kg/m^3 at 100°C. The feed rail pressure is normally 7 bar but experiences pressure "spikes" when the spill valve dumps high pressure fuel into the rail. The drain line pressure is 1 bar and a fuel flow rate of 17 litre/hour through the chamber 32 is required for rail cooling. It has been found in this particular application that the optimum pressure in the chamber for bounce suppression is 2 bar and to achieve this pressure the approximate diameters of the restrictor orifices 46 and 48 are 0.5 mm and 0.7 mm respectively.

Claims

1. A fuel injector incorporating an electromagnetically operated spill valve (18), the armature (28) of the electromagnet being moveable within an armature chamber (32) through which fuel flows in use, and means controlling the flow of fuel through said chamber (32) so that the pressure of fuel within said chamber (32) is such that at least one of the opening and closing bounce of the armature (28) and associated spill valve (18) is mitigated.

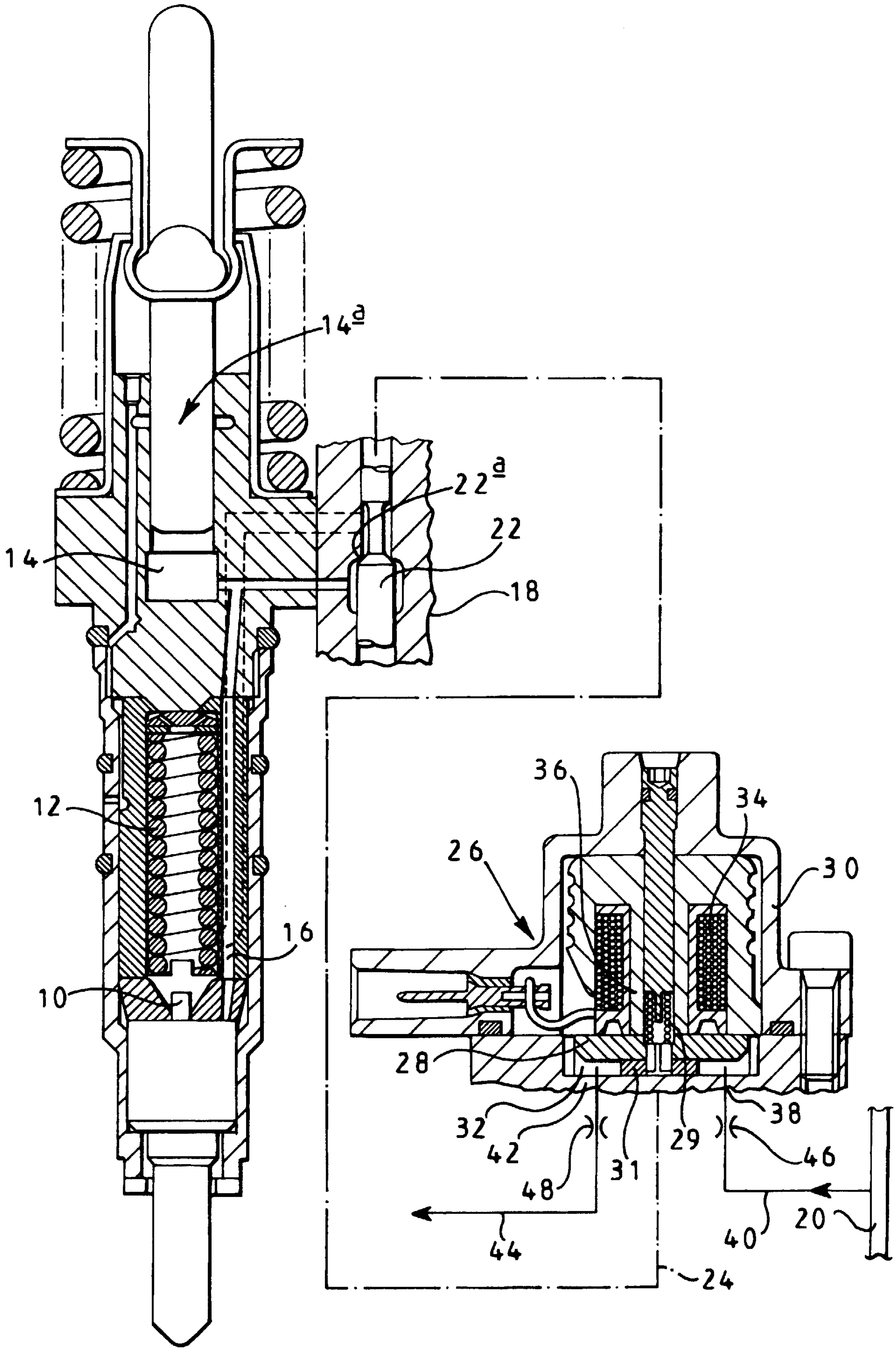
2. A fuel injector as claimed in Claim 1, wherein said means comprises a first flow restrictor (46) in the fuel inlet to said chamber (32), and a second flow restrictor (48) in the fuel outlet from said chamber (32), the values of the restrictions to fuel flow formed by said first and second restrictors (46, 48) being chosen in relation to the system feed and drain pressures and the flow characteristics of the chamber (32), such that the fuel pressure in the chamber reduces the possibility of armature and associated valve bounce at the open and/or closed limits of the spill valve movement.

3. A fuel injector as claimed in Claim 2, wherein the first and second flow restrictors (46, 48) are defined by orifices of diameter 0.5 mm and 0.7 mm respectively.

4. A fuel injector as claimed in any one of the preceding claims, wherein the fuel pressure within the chamber (32) is approximately 2 bar.

5. A fuel injector as claimed in any one of the preceding claims, wherein the means controls the fuel flow rate, holding the rate at approximately 17 litre/hour.

6. A method of manufacturing a fuel injector incorporating an electromagnetically operated spill valve (18), the armature (28) of the electromagnet being moveable within an armature chamber (32) through which fuel flows in use, and means controlling the flow of fuel through said chamber (32) so that the pressure of fuel within said chamber (32) is such that at least one of the opening and closing bounce of the armature (28) and associated spill valve (18) is mitigated, said means comprising a first flow restrictor (46) in the fuel inlet to said chamber (32), and a second flow restrictor (48) in the fuel outlet from said chamber (32), the method including the steps of selecting the size of the first and second flow restrictors (46, 48) to achieve a predetermined fuel pressure within the chamber (32) to reduce the possibility of armature and associated spill valve bounce.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