

(19)



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(11)

**EP 1 163 440 B1**

(12)

## EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention  
of the grant of the patent:

**05.10.2005 Bulletin 2005/40**

(21) Application number: **00911038.8**

(22) Date of filing: **20.03.2000**

(51) Int Cl.7: **F02M 47/02**

(86) International application number:  
**PCT/GB2000/000963**

(87) International publication number:  
**WO 2000/055490 (21.09.2000 Gazette 2000/38)**

(54) **FUEL INJECTOR**

KRAFTSTOFFINJEKTOR

INJECTEUR DE CARBURANT

(84) Designated Contracting States:  
**DE ES FR GB IT**

(30) Priority: **18.03.1999 GB 9906090**  
**03.06.1999 GB 9912913**

(43) Date of publication of application:  
**19.12.2001 Bulletin 2001/51**

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(56) References cited:  
**DE-A- 19 727 896**      **DE-A- 19 826 791**  
**DE-C- 19 519 192**      **FR-A- 2 756 595**

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## Description

**[0001]** This invention relates to a fuel injector for use in delivery of fuel under pressure to a cylinder of an associated compression ignition internal combustion engine. In particular, the invention relates to a fuel injector of the type suitable for use in a fuel supply system of the common rail type, the injector being actuable to permit fuel to be delivered to the cylinder of the associated engine from the common rail, the common rail being charged with fuel under pressure by an appropriate high pressure fuel pump. A plurality of similar injectors is arranged to receive fuel from the common rail.

**[0002]** It is known to control the operation of such a fuel injector by using a valve to control the fuel pressure within a control chamber, the fuel pressure within the control chamber acting upon a surface associated with the needle of the injector to apply a force to the needle urging the needle towards its seating. In order to ensure that injection terminates quickly upon closing the valve, it is known to use a flow restrictor to limit the fuel pressure acting on the needle and urging the needle away from its seating.

**[0003]** By way of background to the present invention, FR 2756595 discloses a fuel injector in which a valve is used to control fuel pressure within a control chamber so as to control movement of a valve needle of the injector within a bore. A piston member is co-operable with the valve needle, a surface of the piston member being exposed to fuel pressure within the control chamber such that a force is applied to the piston member and, hence, to the valve needle, to urge the valve needle towards its seating. Opposite end portions of the piston member and the valve needle define an intermediate chamber, the pressure of fuel within the intermediate chamber being variable, in use, during an injection cycle. The valve for controlling the fuel pressure within the control chamber is of the type in which a valve head is engagable with an orifice in communication with the control chamber so as to control the rate at which fuel is able to escape from the control chamber when it is desired to lift the valve needle from its seating.

**[0004]** According to a first aspect of the invention there is provided a fuel injector comprising a valve needle slidable in a first bore and engagable with a seating to control fuel flow through an outlet, the valve needle including at least one thrust surface oriented such that the application of fuel under pressure thereto applies a force to the valve needle urging the valve needle away from the seating. A valve member is slidable within a further bore and engagable with a further seating defined by the further bore, the further bore defining, together with a region of the valve member, an annular chamber in communication with a control chamber. The valve member controls fuel pressure within the control chamber by controlling communication between the annular chamber and a low pressure source, thereby to control the position of the valve needle relative to the

seating. A piston member is slidable within a second bore, and defines, with the second bore, the control chamber, the piston member being exposed at one end portion thereof to fuel pressure within the control chamber, is cooperable with the valve needle to transmit the force applied by the fuel pressure to the valve needle, and has an effective area exposable to fuel pressure so as to urge the valve needle towards the seating greater than the effective area of the thrust surface or surfaces. Respective opposite end portions of the piston member and the valve needle define, with the first and/or second bore, an intermediate chamber. The injector further comprises a spill passage for spilling fuel within the intermediate chamber to the annular chamber and, thus, to the low pressure source under the control of the valve member, thereby to permit the pressure within the intermediate chamber to be varied during an injection cycle wherein the spill passage is provided with valve means which serve to prevent the over-pressurisation of fuel within the intermediate chamber.

**[0005]** If the intermediate chamber is a closed chamber, there is negligible leakage to low pressure, and pumping losses are consequently minimised. However, some heat energy loss may occur due to flow within the injector. For example, with the valve needle open flow may occur from high-pressure regions, for example from the control chamber by way of a controlled clearance between the piston member and the bore, into the intermediate chamber. This internal flow tends to cause a gradual increase in pressure in the intermediate chamber and a consequential gradual reduction in the internal flow. The volume of internal flow which needs to be recovered into the control chamber at the end of an injection event is therefore self-limiting.

**[0006]** As the volume of the intermediate chamber is reduced during movement of the piston member and the valve needle towards the seating, increasing the pressure in the intermediate chamber still further, subsequent damping of the piston movement may occur, which may result in loss of contact between the piston and valve needle. It has been found that this can be tolerated in certain injection regimes, particularly since the momentum of the valve needle together with the over-pressure in the intermediate chamber acting on the valve needle drives the needle into its closed position in engagement with the seating. Subsequently, leakage of fluid back out of the intermediate chamber, for example to the control chamber, should allow the piston member to return to its original position in engagement with the valve needle. However, the start of the next injection cycle may occur before the piston has time to return fully.

**[0007]** Accordingly, the fuel injector may further comprise resilient biasing means biasing the piston member towards the valve needle. This assists the return of the piston member into engagement with the valve needle in the required time.

**[0008]** The biasing means further assists in sealingly retaining the valve needle against its seat for preventing

the siphoning of fuel into a cylinder of an engine when the engine is not running.

**[0009]** The valve means may be arranged to ensure low pressure is trapped within the intermediate chamber at the onset of closure of the valve needle. This aids relatively rapid closure of the valve needle. Further, the valve means may take the form of a ball valve which may be spring biased into the closed position when the fuel pressure within the intermediate chamber is reduced sufficiently, in use.

**[0010]** The valve means may be arranged within the spill passage. Preferably, the restricted flow path does not communicate directly with the spill passage such that operation of the valve means is substantially unaffected, in use, by the passage of fuel through the restricted flow path.

**[0011]** The present invention is advantageous in that it facilitates a reduction in the pressure differential between the control chamber and the or each thrust surface on the one hand and the intermediate chamber on the other hand, and tends to minimise leakage to low pressure.

**[0012]** In particular, this facilitates a more energy efficient fuel injector than one in which the intermediate chamber is permanently connected to a low-pressure region.

**[0013]** The arrangement is also advantageous in that the use of flow restrictors restricting the rate of fuel flow towards the seating can be avoided, the difference in area producing the biasing force necessary to cause rapid termination of injection. By avoiding the use of flow restrictors, the loss of pressure during injection is reduced.

**[0014]** In this embodiment of the invention, the valve needle may have a greater effective area exposable to fuel pressure within the intermediate chamber than the effective area of the thrust surface or surfaces. This ensures that high pressure in the intermediate chamber tends to urge the valve needle towards the seating.

**[0015]** In order that the invention may be well understood, various embodiments thereof which are given by way of example only, will now be described with reference to the accompanying drawings, in which:

Figure 1 is a sectional view of part of an injector in accordance with a first embodiment;

Figure 2 is a sectional view of part of an injector in accordance with a second embodiment;

Figure 3 is a sectional view of part of an injector in accordance with a third embodiment;

Figure 4 is a sectional view of part of an injector in accordance with a fourth embodiment;

Figure 5 is a sectional view of part of an injector in accordance with a fifth embodiment;

Figure 6 is a sectional view of part of an injector in accordance with a sixth embodiment;

Figure 7 is a sectional view of a part of an injector in accordance with a seventh embodiment of the invention;

Figure 8 is a sectional view of a part of an injector in accordance with an eighth embodiment of the invention; and

Figure 9 is a sectional view of a part of an injector in accordance with a ninth embodiment of the invention; and

**[0016]** The injector illustrated in Figure 1 comprises a valve needle 10, which is slidable within a blind bore 12 formed in a nozzle body 14. The valve needle 10 includes, at its lower end, a frusto-conical surface (not shown) which is arranged to engage a frusto-conical seating (not shown) formed adjacent the blind end of the bore 12, engagement of the valve needle 10 with the seating controlling the supply of fuel from the bore 12 to one or more outlet openings (not shown) which communicate with the bore 12 downstream of the seating.

**[0017]** The bore 12 is shaped to define an annular gallery 20 which communicates with an inlet passage 22 whereby fuel is supplied in the direction of Arrow A from a source of fuel under high pressure, for example a common rail charged with fuel to a high pressure by a suitable high pressure fuel pump. The needle 10 is of stepped form and defines a thrust surface (not shown) which is angled such that the application of fuel under high pressure thereto applies a force to the valve needle urging the valve needle 10 in an upward direction away from the seating, in the orientation illustrated. Similarly, the application of fuel under high pressure to the frusto-conical end region (not shown) of the needle 10 applies a force to the needle 10 urging the needle 10 away from its seating. The needle also has helical recesses 24 extending coaxially therealong for assisting the passage of fuel to the injector outlet. These recesses also provide surfaces, which may assist urging of the valve needle upwards.

**[0018]** The upper end of the nozzle body 14 abuts a piston housing 26 which is shaped to define a blind bore 28 which, preferably, extends coaxially with the bore 12 of the nozzle body 14. Alternatively, the bore 28 could be axially offset with respect to the bore 12 so as to provide sufficient space for the inlet passage 22.

**[0019]** A piston 36 is located in the bore 28 in sliding engagement with the bore 28. The piston 36 and upper end of the bore 28 together define a control chamber 38, which communicates, through a passage 40, provided with a restriction 40a, with the supply passage 22. A closed intermediate chamber 44 is formed between the piston 36 and valve needle 10. The chamber is defined by the lower surface of the piston 36, the upper surface

34 of the valve needle 10 and the portions of bores 12 and 28 which lie intermediate these surfaces. A thrust pin 42 of relatively short axial length extends from the lower portion of the piston 36 into engagement with the upper surface 34 of the valve needle 10. A helical compression spring 43 is situated in the control chamber 38 in abutment with the roof of the chamber 38 and an upper surface of the piston 36, so as to resiliently bias the piston 36 with thrust pin 42 towards engagement with the valve needle 10.

**[0020]** The upper surface of the piston housing 26 abuts the lower surface of a valve housing 45 which is provided with a through bore 46 within which a control valve member 48 is slidable. The control valve member 48 includes an upper end region of enlarged diameter which is engagable with a seating 50 defined around an upper end of the through bore 46. The upper end of the valve member 48 is connected to an armature 52 which is moveable under the influence of a magnetic field generated, in use, by an actuator including windings 56. A spring 58 is arranged to bias the valve member 48 into engagement with the seating 50. The actuator and spring 58 are located within a nozzle holder 60, a cap nut (not shown) being in screw-threaded engagement with the nozzle holder 60 and securing the nozzle body 14, the piston housing 26 and the valve housing 45 to the nozzle holder 60.

**[0021]** The control chamber 38 communicates through passages 64 with an annular chamber defined between a region of the valve member 48 of reduced diameter and the bore 46 within which the valve member 48 is slidable. The part of the passage 64 provided in the housing 26 is provided with a restriction 64a to restrict the rate of fuel flow therethrough, as will be described in further detail herein after. When the valve member 48 engages its seating 50, the valve member 48 is substantially fuel pressure balanced, and the spring 58 is of sufficient strength to cause the valve member 48 to remain in this position. Energization of the actuator results in movement of the valve member 48 away from the seating 50 against the action of the spring 58 resulting in fuel being permitted to flow from the control chamber 38 to a chamber 66 within which the armature 52 is located, the chamber 66 communicating through a passage 67 with a low pressure drain or reservoir to which fuel flows in the direction of Arrow B. De-energization of the actuator allows the valve member 48 to return to the position illustrated under the action of the spring 58.

**[0022]** In use, with the actuator de-energized and with the supply passage 22 supplied with fuel under high pressure from an appropriate source, for example a common rail charged with fuel under high pressure by an appropriate pump, it will be appreciated that the thrust surface of the valve needle 10 and the exposed part of the frusto-conical surface of the valve needle 10 are supplied with fuel under pressure, and thus a force is applied to the valve needle 10 urging the needle 10

away from its seating. This force is opposed by the action of the spring 43 and by the action of fuel under pressure within the control chamber 38 upon the exposed end surfaces of the piston 36. The effective area of the piston 36 exposed to the fuel pressure within the control chamber 38 is greater than the effective areas of the thrust surface and the exposed part of the frusto-conical surface of the valve needle. It will be appreciated that the net force applied to the needle 10 is a downward force, urging the valve needle 10 to remain in engagement with its seating. This downward force has components provided by the spring 43 and the force exerted on the top of the needle 10 by the pressurised fuel in the intermediate chamber. In this connection, the effective area at the top of the valve needle 10 that is exposed to pressure is greater than the effective areas of the thrust surface and the frusto-conical surface of the valve needle 10, to assist in holding the valve closed once pressure has built up in the intermediate chamber 44. Therefore, injection does not occur in this condition.

**[0023]** In order to commence injection, the actuator is energized resulting in upward movement of the valve member 48 against the action of the spring 58. Such movement of the valve member 48 permits fuel to escape from the control chamber 38 thus reducing the fuel pressure applied to the piston 36. It will be appreciated that the presence of the restricted passage 40, 40a restricts the rate at which fuel flows to the control chamber 38 from the supply passage 22, thus the movement of the valve member 48 away from the seating 50 results in a reduction in the fuel pressure within the control chamber 38. It will further be appreciated that the rate of pressure drop in the control chamber 38, and the final low pressure level in the control chamber 38, can be controlled by appropriate sizing of the restrictions 40a, 64a.

**[0024]** The reduction in fuel pressure applied to the top of the piston 36 gives rise to a pressure difference between the control chamber 38 and the exposed annular area of the valve needle 10 at its lowermost tip region (i.e. the frusto-conical surface which is engageable with the valve needle seating), the pressure difference being sufficient to lift the piston 36 and the valve needle 10 in an upwards direction. Thus, a point will be reached beyond which the valve needle 10 is able to move away from its seating, thus permitting fuel to flow to the outlet openings, and through the openings to the cylinder or combustion space of the associated engine within which the injector is mounted.

**[0025]** The volume of the control chamber 38 is relatively small, and as upward movement of the valve needle 10 occurs, a pin 68 forming the upper end of the piston member 36 may move into engagement with the blind end of the bore 28 thus acting to limit upward movement of the piston member 36 and the valve needle 10.

**[0026]** It will be appreciated that, during injection, a small quantity of fuel flows from the supply passage 22

through the restricted passage 40, 40a to the control chamber 38 and from the control chamber 38 through the restricted passage 64, 64a, past the control valve seating 50 to the low pressure drain. The dimensions of the restricted passages 40, 40a, 64, 64a are chosen to ensure that the quantity of fuel under pressure, which is able to escape in this manner, is minimised.

**[0027]** In order to terminate injection, the actuator is de-energized and the valve member 48 returns into engagement with the seating 50 under the action of the spring 58. Such movement of the valve member 48 prevents further fuel from escaping from the control chamber 38 to the low pressure drain, and the continued supply of fuel through the restricted passage 40 to the control chamber 38 results in the fuel pressure within the control chamber 38 increasing. Clearly, therefore, the fuel pressure applied to the piston member 36 and hence the force transmitted through the thrust pin 42 to the valve needle 10 is increased, and a point will be reached beyond which the action of the fuel pressure within the control chamber 38 in combination with the action of the spring 43 is sufficient to cause the valve needle 10 to move towards engagement with its seating, to terminate the supply of fuel to the outlet openings and terminate injection. As the effective area of the piston 36 is greater than that of the thrust surfaces of the needle, such movement of the piston 36 and valve needle 10 occurs rapidly.

**[0028]** It will be appreciated that as the thrust pin 42 is of relatively short axial length, even though the thrust pin 42 is of small diameter, for example 2mm, flexing or compression of the thrust pin 42 to a significant extent does not occur. As a result, when the fuel pressure within the control chamber 38 reduces when injection is to commence, the initial movement of the piston 36 does not simply result in extension of the thrust pin 42 but rather the valve needle 10 commences movement immediately. Jerky movement of the injector needle is therefore reduced or avoided, and injection is more controlled. Although in the description hereinbefore the thrust pin 42 is described as being an extension of the piston, it will be appreciated that the thrust pin may form a separate component or an extension of the valve needle, if desired.

**[0029]** It should be noted that, with the valve needle 10 in the closed position, flow of high-pressure fuel around the piston 36 and needle 10 into the intermediate chamber 44 may increase the pressure in the intermediate chamber 44. In such a case there is still a net force, resulting from the biasing force of the spring 43 and the fuel pressure within the control chamber 38, holding the valve needle 10 against the seating. During opening movement of the valve needle 10, the volume of the intermediate chamber 44 increases and the pressure therein reduces further. This ensures the area advantage provided by the effective area of the piston 36 being greater than the effective area of the valve needle thrust surfaces, is maintained.

**[0030]** Any high pressure fuel leakage into the intermediate chamber 44 during lifting of the piston 36 or with the piston 36 in the uppermost position will contribute to causing an over-pressure in the intermediate chamber 44 once the piston 36 moves downwards to close the valve needle 10 against the seating. However, this does not prevent rapid valve closure because the initially relatively low pressure in the intermediate chamber 44 on commencement of the downward stroke of the piston 36 enables the piston to impart sufficient momentum to the valve needle 10 to bring the valve needle 10 against the seating. However, the downward movement of the piston may be damped as the fuel, including leakage fuel, in the intermediate chamber 44 is compressed. Separation of the piston 36 and valve needle 10 may then occur. If the time between injections is sufficient, the spring 43 will return the piston 36 into engagement with the valve needle 10.

**[0031]** Whilst damping of the downward piston movement and separation of the piston 36 and valve needle 10 may be tolerated in some injection regimes, various modifications of the aforescribed embodiment will now be described which mitigate against such problems by venting the intermediate chamber into the control chamber. In the following description of these modifications, a detailed description of features that are identical to those described with respect to Figure 1 is omitted.

**[0032]** Figure 2 shows a modified injector which is substantially identical to the injector of Figure 1 except for a vent passage 72 through the piston member 36A and a valve member 74 disposed in the control chamber 38A. The valve member 74 is resiliently biased against a seat on the top of piston 36A by a spring 43A, whereby one end of the vent passage 72 is closed off. The vent passage 72 provides fluid communication between the intermediate chamber 44A and the control chamber 38A when over-pressure in the intermediate chamber 44A lifts the valve member 74 from its seat on the upper surface of the piston 36A, for example, when the piston is driven downwards and reduces the volume of the intermediate chamber 44A into which high pressure fuel has leaked. This opening of the vent passage 72 to relieve the pressure in the intermediate chamber 44A alleviates the aforementioned problem of piston damping. Clearly, the plate-valve valve member shown could be substituted for another type of one-way valve, for example a one-way valve having a valve spring in addition to the piston-biasing spring or including a valve member of an alternative form, such as a ball valve.

**[0033]** Figure 3 shows another modified injector which is substantially identical to the injector of Figure 1 except for a vent passage 82 through the piston housing 26A and valve means, shown as a ball valve 84, 85 closing off an end of the vent passage 82. The vent passage 82 provides fluid communication between the intermediate chamber 44B and the control chamber 38B so as to by-pass the piston 36B when over-pressure in the intermediate chamber 44 lifts the ball 84 of the ball

valve against its spring 85.

**[0034]** Figure 4 shows a still further modified injector which is substantially identical to the injector of Figure 1 except for a vent passage 92 through the piston 36C, the lower end of the vent passage opening into a lower face of the piston 36C which mates with the end face 34C of the valve needle 10C in a fluid-tight manner so as to close the vent passage 92 when the piston 36C and valve needle 10C are driven towards one another. If over-pressure occurs in the intermediate chamber 44C such that the piston 36C and valve needle 10C separate from one another as the piston 36C and valve needle 10C are being driven downwards, the lower end of the vent passage 92 opens to the intermediate chamber 44C, relieving the pressure in the intermediate chamber 44C into the control chamber 38C. When the pressure in the intermediate chamber has dropped sufficiently, the piston 36C is driven by the spring 43C back towards engagement with the valve needle 10C so as to reseal the lower end of the vent passage 92.

**[0035]** Figure 5 shows a still further modified injector that is similar to the injector of Figure 1 except that the control chamber 38D communicates with the intermediate chamber 44D through a passageway 102 in the piston 36D. Also, no lower thrust pin is provided on the piston 36D, and the valve needle 10 is provided at its upper end with a reduced diameter portion 10D, shown in abutment with the piston's lower end face. A flow restrictor in the form of a reduced diameter bore portion 103 is provided in the passageway 102. An unrestricted spill passageway 104 is provided in the piston housing 26D for spilling fuel from the intermediate chamber 44D to low pressure via chamber 66 under control of the valve member 48. In the embodiment of Figure 5, all spill flow must first pass through the passageway in the piston 36D and is thus subject to the flow restrictor 103.

**[0036]** The injector in Figure 5 is shown in the closed condition between injections, with the valve member 48 in the closed position. When valve member 48 is opened, the pressure in the intermediate chamber 44D is quickly spilt. The pressure within the control chamber 38D is reduced as fuel flows through the passage 102 and the restricted passage 103, the valve needle 10 and the piston 36D consequently move quickly upwards under the force exerted on thrust surface 105 and on the frusto-conical surface on the valve needle tip by the high pressure fluid from inlet passage 22, overcoming the reduced force due to reduced fuel pressure within the control chamber 38 and the force of the spring 43D, thereby opening the injector. It will be appreciated that, as the intermediate chamber 44D is essentially evacuated, the force applied to the top of the piston 36D and the force applied to the frusto-conical surface of the valve needle tip, will serve to hold the valve needle 10 and the piston 36D together.

**[0037]** When the valve member 48 is closed fluid continues to flow through the passageway 102, maintaining a pressure differential across the flow restrictor 103.

This drives the piston 36D downwardly, thereby driving downwardly the valve needle 10, which is in engagement with the piston 36D, against its seating. The pressure differential across the restrictor 103 gradually reduces until the pressures in the control chamber 38D and intermediate chamber 44D have equalised. It should be apparent that the intermediate chamber pressure drops below the inlet passage pressure for a short period only, thereby minimising heat losses within the injector.

**[0038]** Figure 6 shows a still further modified injector that is similar to the injector of Figure 1 except that the intermediate chamber 44E communicates through a passageway 106 both with a restricted passage 107 into the control chamber 38E and a spill passage 108 for spilling fluid to a low pressure sink via chamber 66 under control of the valve member 48. Also, a coil spring 109 is disposed in the intermediate chamber 44E about a reduced diameter thrust pin portion 42E of the piston 36E. The spring 109 engages mutually opposite annular surfaces 111, 110 of the piston 36E and the needle 10 respectively so as to bias the needle 10 away from the piston 36E and ensure that there is always a closing force acting on the needle 10.

**[0039]** The valve needle 10 may be provided at its upper end with a reduced diameter portion 10E, similar to the portion 10D shown in Fig 5.

**[0040]** Figure 6 shows the injector in normal operation with the valve member 48 closed and the piston 36E in contact with the valve needle 10. Whilst, when pressure in the control chamber 38E and the intermediate chamber 44E has equalised, the spring 109 tends to drive the piston 36E upwards, away from the valve needle 10, in normal operation there is not enough time for this to occur between injections. In the condition shown, when the valve member 48 opens and reduces pressure in the intermediate chamber 44E the upward thrust on the valve needle 10 via thrust surface 105 and the frusto-conical surface on the valve needle tip, gradually drives the valve needle 10 with the piston 36E upwards and into the open position, overcoming the force due to reduced fuel pressure in the control chamber 38.

**[0041]** When the valve member 48 is closed, the pressure differential between the control chamber 38E and the intermediate chamber 44E across the restriction 107 results in a downward force on the piston 36E which drives the valve needle 10 downwardly to close the injector. If a long enough period elapses before the valve member 48 opens again the pressure differential is eroded by flow through the restriction 107 to the intermediate chamber 44E, and the spring 109 may drive the piston 36E upwardly as already described.

**[0042]** In this embodiment, losses are reduced in that the intermediate chamber pressure is maintained above the pressure of the low pressure sink for most, or at least some, of the injection cycle.

**[0043]** Referring to Figure 7, there is shown a further alternative embodiment of the invention in which the

control chamber 38F communicates with the annular chamber defined between the reduced diameter region of the valve member 48 and the bore 46 by means of a restricted passage 65. The fuel injector also includes a spill passage 81 which provides a return path for fuel from the intermediate chamber 44F to the passage 65 and, thus, past the valve seating 50 whilst the valve member 48 is open. The passage 81 is provided in the piston housing 26 for the piston member 36F and valve means, in the form of a one-way ball valve 83, are provided towards the upper end of the passage 81. The ball valve 83 is engageable with a seating 86 so as to close communication between the passage 81 and the passage 65. If the pressure in the intermediate chamber 44F exceeds the pressure within the passage 65, the ball valve 83 in the passage 81 is lifted from its seating 86, thereby permitting fuel to flow from the intermediate chamber 44F into the passage 65. If the pressure in the intermediate chamber 44F does not exceed that in the passage 65, the one way ball valve 83 remains in its seating 86 and prevents any flow of fuel from the passage 65, in communication with the control chamber 38F, into the intermediate chamber 44F. Operation of the ball valve 83 will be described in further detail herein after.

**[0044]** The passage 65 includes a flow restriction 65a, and as a result when the control valve is open the pressure within the passage 65 downstream of the flow restriction is, for at least part of the operating cycle of the injector, lower than that within the control chamber 38F. The intermediate chamber 44F can thus be vented to a pressure lower than that within the control chamber 38F.

**[0045]** Operation of the injector in Figure 7 is substantially the same as described previously such that, in order to commence injection, the valve member 48 is moved upwardly to permit fuel to escape from the control chamber 38F, thereby reducing the fuel pressure applied to the piston 36F. The ball valve 83 also opens such that the intermediate chamber 44 is depressurised. The flow restriction in the restricted passage 65 causes the pressure downstream of the restriction to fall to a level lower than that within the control chamber 38F. For example, whilst the control valve 48 is open, the control chamber pressure may fall to a level, typically, within the range 50 to 60% of the pressure within the common rail or other source of fuel under pressure, the pressure within the restricted passage 65, 65a downstream of the flow restriction falling, typically, within the range 10 to 20% of the rail or other source pressure. As a result, the intermediate chamber pressure falls rapidly, and may fall to a level lower than that within the control chamber 38F, prior to commencement of movement of the piston member and needle. During movement of the piston 36F and valve needle 10, the volume of the intermediate chamber 44F increases and so the fuel pressure therein falls further, and a cavity may be formed therein.

**[0046]** The ball valve may be provided with a bias spring (not shown) to bias the ball valve 83 into its seat-

ing 86. However, this is not essential as the fuel pressure in the passage 65 is usually sufficient to keep the ball valve seated when required.

**[0047]** The provision of the ball valve 83 ensures that, if pressure in the intermediate chamber 44F exceeds that within the passage 65, the ball valve 83 will open. Following movement of the piston 36F in an upwards direction, the pressure in the intermediate chamber 44F will start to decrease and the ball valve 83 will return to its seated position against its seating 86. The provision of the ball valve 83 therefore ensures low pressure remains "trapped" in the intermediate chamber 44F. This minimises any damping of the downward movement of the piston member 36F, and the valve needle 10, at the onset of closure of the valve needle 10. The ball valve 83 also serves to relieve the pressure within the intermediate chamber 44F should the intermediate chamber 44F become over-pressurised. If the ball valve 83 is provided with a bias spring for urging the ball valve 83 towards its seating 86, it will be appreciated that the ball valve 83 may be seated more quickly, prior to the commencement of upward movement of the piston 36F.

**[0048]** In order to terminate injection, the actuator is de-energized and the valve member 48 returns into engagement with the seating 50 under the action of the spring 58, as described previously.

**[0049]** It should be noted that, with the valve needle 10 in the closed position, flow of high-pressure fuel around the piston 36F and needle 10 into the intermediate chamber 44F may increase the pressure in the intermediate chamber 44F. In such a case there is still a net force, resulting from the biasing force of the spring 43 and the fuel pressure within the control chamber 38F, holding the valve needle 10 against the seating. As the valve needle 10 and piston 36F move upwards at the commencement of injection, the fuel pressure acting thereon assisting the spring 43 in keeping them together, the volume of the intermediate chamber 44F increases, further reducing the pressure therein. Any high pressure fuel leakage into the intermediate chamber 44F during lifting of the piston 36F, or with the piston 36F in the uppermost position, may contribute to causing an over-pressure in the intermediate chamber 44F once the piston 36F moves downwards to close the valve needle 10 against the seating. However, if the pressure in the intermediate chamber 44F exceeds that within the passage 65, the ball valve 83 in the passage 81 is caused to lift from its seating 86, thereby permitting fuel to flow from the intermediate chamber 44F into the passage 65 and reducing the fuel pressure within the intermediate chamber 44F.

**[0050]** The arrangement of the passage 81 within the piston housing 26, and the provision of the ball valve 83 within the passage 81, is convenient to construct as the ball valve can be located in the region of contact between the upper valve member housing 45 and the piston housing 26. Furthermore, as the volume of the control chamber 38F is relatively small, when it is desired

to cease fuel injection, repressurisation of the control chamber 38F can therefore be achieved relatively rapidly. Additionally, on actuation of the valve member 48, and movement of the valve needle 10 away from its seating, the intermediate chamber 44F is depressurised to a low pressure, and is able to accept a relatively large volume of fuel leaking past the piston 36F as the valve needle 10 is lifted away from its seating. Thus, the intermediate chamber 44F is less likely to fill with fuel to a high pressure during the fuel injecting part of the cycle.

**[0051]** It will be appreciated that the ball valve 83 disposed within the passage 81 may be substituted for another type of one-way valve, for example a one-way valve having a valve spring, both one-way valves of the type which are spring biased and those which are not spring biased being suitable for use in the passage. In a further alternative embodiment to that shown in Figure 7, the ball valve may be arranged lower down the passage 81, closer to the nozzle body 14.

**[0052]** Figure 8 illustrates an arrangement which, in many respects, is similar to that of Figure 7 and only the differences therebetween are described in detail. The arrangement of Figure 8 is distinguished from that of Figure 7 in that the spring 43 is located within the intermediate chamber 44F rather than within the control chamber 38F. As a result, the volume of the control chamber 38F can be reduced thus the pressure changes which are necessary to operate the injector can be achieved rapidly, improving the responsiveness of the injector. The spring 43 engages a washer 43a which engages a step 28a formed in the bore 28. If desired, the thickness of the washer 43a may be selected to adjust the spring load applied to the needle. Alternatively, a shim of an appropriate thickness may be located between the spring 43 and the washer 43a.

**[0053]** A possible disadvantage of the arrangement in Figures 7 and 8 is that operation of the ball valve 83 may be affected by any fuel ejected through the restriction 65a upon opening movement of the valve member 48. Figure 9 shows an alternative embodiment to that shown in Figures 7 and 8 which avoids this problem. In this embodiment, the valve housing 45 is provided with an additional drilling defining a passage 90 which provides communication between the control chamber 38 and the low pressure drain when the valve member 48 is moved away from its seating 50. The passage 90 includes a restriction 90a defined in a part of the passage defined in the piston housing 26. The injector in Figure 9 also includes a spring 92 which serves to urge the ball valve 83 against its seating 86. It will be appreciated, however, the provision of the spring 92 is not essential, as described previously.

**[0054]** The arrangement in Figure 9 provides the advantage that, as the ball valve 83 is located in a separate passage (passage 81) from the passage between the control chamber 38 and the valve seating 50 (i.e. passage 90), any fuel ejected from the restriction 90a upon opening movement of the valve member 48 will not ef-

fect operation of the ball valve 83.

## Claims

1. A fuel injector comprising: a valve needle (10) slidable in a first bore (12) and engagable with a seating to control fuel flow through an outlet, the valve needle including at least one thrust surface oriented such that the application of fuel under pressure thereto applies a force to the valve needle urging the valve needle away from the seating; a valve member (48) slidable within a further bore (46) and engageable with a further seating (50) defined by the further bore (46), the further bore (46) defining, together with a region of the valve member (48), an annular chamber in communication with a control chamber (38F), the valve member controlling fuel pressure within the control chamber (38F) by controlling communication between the annular chamber and a low pressure source, thereby to control the position of the valve needle (10) relative to the seating; and a piston member (36) slidable within a second bore (28), and defining, with the second bore (28), the control chamber (38F), wherein the piston member is exposed at one end portion thereof to fuel pressure within the control chamber (38F), is cooperable with the valve needle (10) to transmit the force applied by the fuel pressure to the valve needle, and has an effective area exposable to fuel pressure so as to urge the valve needle towards the seating greater than the effective area of the thrust surface or surfaces, respective opposite end portions of the piston member (36) and the valve needle (10) defining, with the first (12) and/or second bore (28), an intermediate chamber (44F), the injector further comprising a spill passage (81, 104) for spilling fuel within the intermediate chamber (44F) to the annular chamber and, thus, to the low pressure source under the control of the valve member (48), thereby to permit the pressure within the intermediate chamber (44F) to be varied during an injection cycle, and wherein the spill passage (81) is provided with valve means (83, 86) which serve to prevent the over-pressurisation of fuel within the intermediate chamber (44F).
2. A fuel injector as claimed in Claim 1, wherein the intermediate chamber (44F) communicates with the control chamber (38F) along a restricted flow path (65a; 65; 90, 90a) so as to cause a pressure differential between the chambers (38F, 44F).
3. A fuel injector as claimed in Claim 2, wherein the restricted flow path (65; 65a; 90, 90a) is through a piston housing (26).
4. A fuel injector as claimed in any of Claims 1 to 3,

wherein the valve means (83, 86) are arranged to ensure low pressure is trapped within the intermediate chamber (44F) at the onset of closure of the valve needle (10).

5. A fuel injector as claimed in any of Claims 1 to 4, wherein the valve means take the form of a ball valve (83).
6. A fuel injector as claimed in Claim 5, wherein the ball valve (83) includes a bias spring to bias the ball valve into the closed position when the fuel pressure within the intermediate chamber (44F) is reduced sufficiently, in use.
7. A fuel injector as claimed in any of Claims 1 to 6, wherein the valve means (83, 86) are arranged within the spill passage (81).
8. A fuel injector as claimed in Claim 7, wherein the restricted flow path (90, 90a) does not communicate directly with the spill passage (81) such that operation of the valve means (83) is substantially unaffected, in use, by the passage of fuel through the restricted flow path (90, 90a).
9. A fuel injector as claimed in any one of Claims 1 to 8, further comprising resilient biasing means (43, 43a) biasing the piston member (36) towards the valve needle (10).
10. A fuel injector as claimed in Claim 9, wherein the resilient bias means (43, 43a) are either arranged within the intermediate chamber (44F) or within the control chamber (38F).
11. A fuel injector as claimed in any of Claims 1 to 10, wherein the valve needle (10) has a greater effective area exposable to fuel pressure within the intermediate chamber (44F) than the effective area of the thrust surface or surfaces.

#### Patentansprüche

1. Krafteinspritzventil, umfassend: eine Ventilnadel (10), die in einer ersten Bohrung (12) verschieblich angeordnet ist und an einem Sitz zur Anlage gelangen kann, um den Fluss von Kraftstoff durch einen Auslass zu steuern, wobei die Ventilnadel mindestens eine Druckfläche aufweist, die so ausgerichtet ist, dass das Aufbringen von unter Druck stehendem Kraftstoff darauf eine Kraft auf die Ventilnadel ausübt, die die Ventilnadel weg von dem Sitz drückt; ein Ventilelement (48), das innerhalb einer weiteren Bohrung (46) verschieblich angeordnet ist und an einem weiteren Sitz (50) zur Anlage gelangen kann, der von der weiteren Bohrung (46) gebildet wird,

wobei die weitere Bohrung (46) zusammen mit einem Bereich des Ventilelements (48) eine ringförmige Kammer bildet, die in Verbindung mit einer Steuerkammer (38F) steht und das Ventilelement den Kraftstoffdruck innerhalb der Steuerkammer (38F) durch das Steuern der Verbindung zwischen der ringförmigen Kammer und einer Niederdruck-Quelle steuert, um hierdurch die Stellung der Ventilnadel (10) relativ zu dem Sitz zu steuern; und ein Kolbenelement (36), das innerhalb einer zweiten Bohrung (28) verschieblich angeordnet ist und zusammen mit der zweiten Bohrung (28) die Steuerkammer (38F) bildet, wobei das Kolbenelement an einem seiner Endteile dem Kraftstoffdruck innerhalb der Steuerkammer (38F) ausgesetzt ist, mit der Ventilnadel (10) zusammenwirkt, um die vom Kraftstoffdruck aufgebrauchte Kraft auf die Ventilnadel (10) zu übertragen, und einen zum Zwecke des Drückens der Ventilnadel in Richtung des Sitzes dem Kraftstoffdruck aussetzbaren wirksamen Flächenbereich besitzt, der größer als der wirksame Flächenbereich der Druckfläche oder Druckflächen ist, wobei entsprechende einander gegenüberliegende Endteile des Kolbenelements (36) und der Ventilnadel (10) zusammen mit der ersten (12) und/oder zweiten Bohrung (28) eine Zwischenkammer (44F) bilden, und wobei das Einspritzventil weiterhin einen Überströmkanal (81, 104) zum Abfließen von Kraftstoff innerhalb der Zwischenkammer (44F) unter der Steuerung des Ventilelements (48) zur ringförmigen Kammer und damit zu der Niederdruck-Quelle aufweist, wodurch es möglich ist, dass der Druck innerhalb der Zwischenkammer (44F) während eines Einspritz-Zyklus verändert wird, und worin der Überströmkanal (81) mit Ventilmitteln (83, 86) versehen ist, die dazu dienen, einen übermäßigen Anstieg des Kraftstoffdrucks innerhalb der Zwischenkammer (44F) zu verhindern.

2. Kraftstoffeinspritzventil nach Anspruch 1, worin die Zwischenkammer (44F) entlang eines verengten Durchflusses (65a; 65; 90, 90a) mit der Steuerkammer (38F) in Verbindung steht, um eine Druckdifferenz zwischen den Kammern (38F, 44F) zu bewirken.
3. Kraftstoffeinspritzventil nach Anspruch 2, worin der verengte Durchflussweg (65; 65a; 90, 90a) durch ein Kolbengehäuse (26) führt.
4. Kraftstoffeinspritzventil nach einem der Ansprüche 1 bis 3, worin die Ventilmittel (83, 86) so angeordnet sind, dass sie sicherstellen, dass niedriger Druck zu Beginn des Schließens der Ventilnadel (10) innerhalb der Zwischenkammer (44F) eingefangen oder eingeschlossen wird.
5. Kraftstoffeinspritzventil nach einem der Ansprüche

1 bis 4, worin die Ventilmittel die Form eines Kugelventils (83) annehmen.

6. Kraftstoffeinspritzventil nach Anspruch 5, worin das Kugelventil (83) eine Verspannfeder umfasst, die das Kugelventil in die geschlossene Stellung spannen soll, wenn der Kraftstoffdruck während des Betriebs innerhalb der Zwischenkammer (44F) ausreichend abgesenkt wird. 5
7. Kraftstoffeinspritzventil nach einem der Ansprüche 1 bis 6, worin die Ventilmittel (83, 86) innerhalb des Überströmkanals (81) angeordnet sind. 10
8. Kraftstoffeinspritzventil nach Anspruch 7, worin der verengte Durchflussweg (90, 90a) nicht direkt mit dem Überströmkanal (81) in Verbindung steht, so dass die Betätigung des Ventilmittels (83) während des Betriebs im Wesentlichen vom Durchtritt von Kraftstoff durch den verengten Durchflussweg (90, 90a) unbeeinflusst bleibt. 15 20
9. Kraftstoffeinspritzventil nach einem der Ansprüche 1 bis 8, weiterhin umfassend elastische Spannmittel (43, 43a), die das Kolbenelement (36) in Richtung der Ventalnadel (10) spannen. 25
10. Kraftstoffeinspritzventil nach Anspruch 9, worin die elastischen Spannmittel (43, 43a) entweder innerhalb der Zwischenkammer (44F) oder innerhalb der Steuerkammer (38F) angeordnet sind. 30
11. Kraftstoffeinspritzventil nach einem der Ansprüche 1 bis 10, worin die Ventalnadel (10) einen dem Kraftstoffdruck innerhalb der Zwischenkammer (44F) aussetzbaren wirksamen Flächenbereich besitzt, der größer ist als der wirksame Flächenbereich der Druckfläche oder der Druckflächen. 35

## Revendications

1. Injecteur de carburant comprenant : un pointeau de soupape (10) pouvant coulisser dans un premier alésage (12) et pouvant entrer en prise avec un portage pour contrôler le débit de carburant à travers un orifice de sortie, le pointeau de soupape comprenant au moins une surface de poussée orientée de sorte que l'application de carburant sous pression sur celle-ci applique une force sur le pointeau de soupape poussant le pointeau de soupape pour l'éloigner du portage ; un élément de soupape (48) pouvant coulisser à l'intérieur d'un autre alésage (46) et pouvant entrer en prise avec un autre portage (50) défini par l'autre alésage (46), l'autre alésage (46) définissant, conjointement avec une région de l'élément de soupape (48), une chambre annulaire en communication avec une chambre de com- 45 50

mande (38F), l'élément de soupape contrôlant la pression de carburant à l'intérieur de la chambre de commande (38F) en contrôlant la communication entre la chambre annulaire et une source de basse pression, pour ainsi contrôler la position du pointeau de soupape (10) par rapport au portage ; et un élément de piston (36) pouvant coulisser à l'intérieur d'un second alésage (28), et définissant, avec le second alésage (28), la chambre de commande (38F), dans lequel l'élément de piston est exposé au niveau d'une partie d'extrémité de celui-ci à la pression de carburant à l'intérieur de la chambre de commande (38F), peut coopérer avec le pointeau de soupape (10) pour transmettre la force appliquée par la pression de carburant sur le pointeau de soupape, et a une surface utile pouvant être exposée à la pression de carburant afin de pousser le pointeau de soupape vers le portage plus importante que la surface utile de la surface ou des surfaces de poussée, des parties d'extrémité opposées respectives de l'élément de piston (36) et du pointeau de soupape (10) définissant, avec le premier (12) et/ou second alésage (28), une chambre intermédiaire (44F), l'injecteur comprenant en outre un passage de déversement (81, 104) pour déverser le carburant à l'intérieur de la chambre intermédiaire (44F) vers la chambre annulaire et, ainsi, vers la source de basse pression sous le contrôle de l'élément de soupape (48), pour ainsi permettre à la pression à l'intérieur de la chambre intermédiaire (44F) d'être variée au cours d'un cycle d'injection, et dans lequel le passage de déversement (81) est pourvu de moyens de soupape (83, 86) qui servent à empêcher la surpressurisation de carburant à l'intérieur de la chambre intermédiaire (44F).

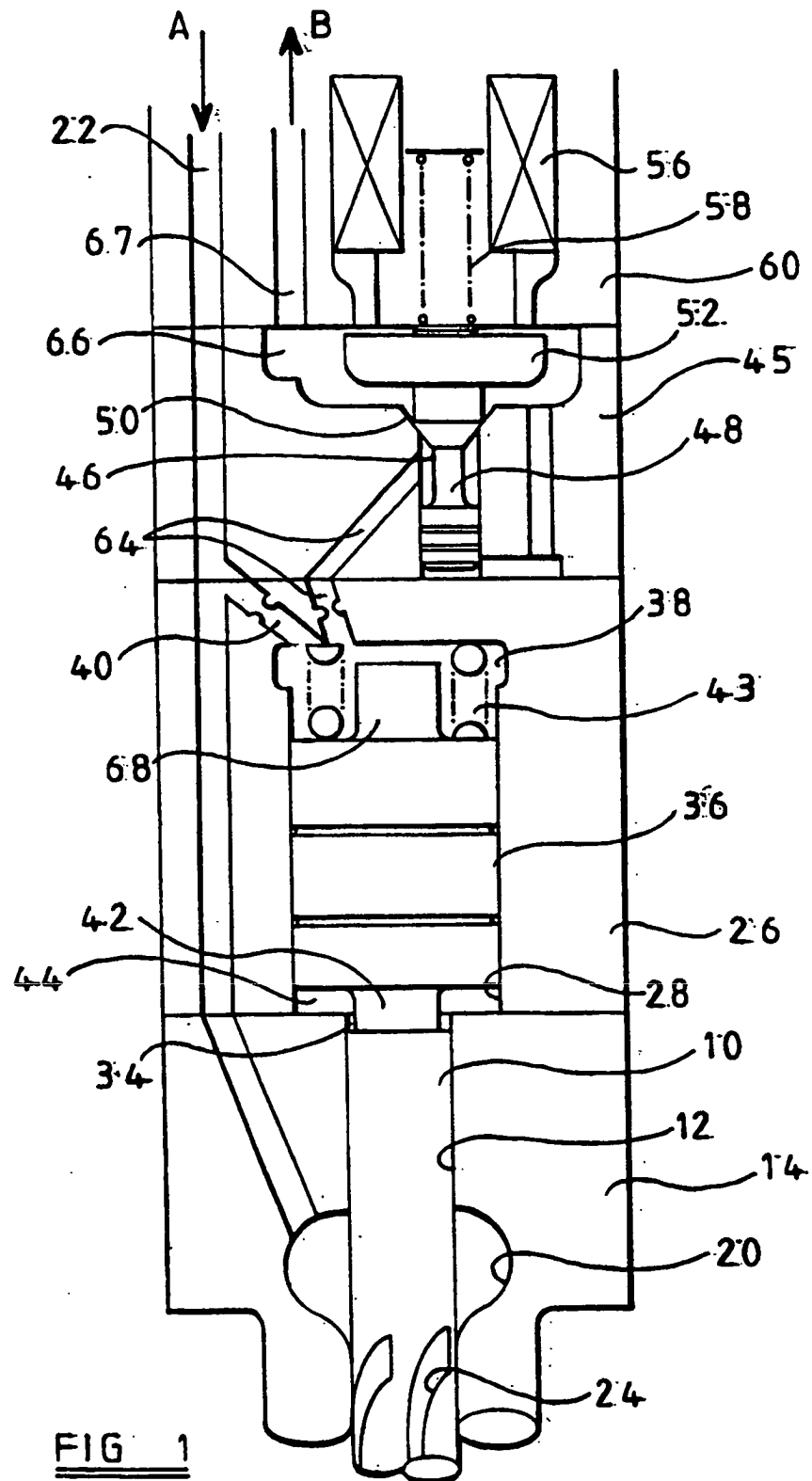
2. Injecteur de carburant selon la revendication 1, dans lequel la chambre intermédiaire (44F) communique avec la chambre de commande (38F) le long d'un passage de débit limité (65a ; 65 ; 90, 90a) afin d'entraîner une pression différentielle entre les chambres (38F, 44F). 40
3. Injecteur de carburant selon la revendication 2, dans lequel le passage de débit limité (65 ; 65a ; 90, 90a) est à travers un logement de piston (26).
4. Injecteur de carburant selon l'une quelconque des revendications 1 à 3, dans lequel les moyens de soupape (83, 86) sont agencés pour s'assurer que la basse pression est coincée à l'intérieur de la chambre intermédiaire (44F) au début de la fermeture du pointeau de soupape (10).
5. Injecteur de carburant selon l'une quelconque des revendications 1 à 4, dans lequel les moyens de soupape prennent la forme de une soupape sphérique (83). 55

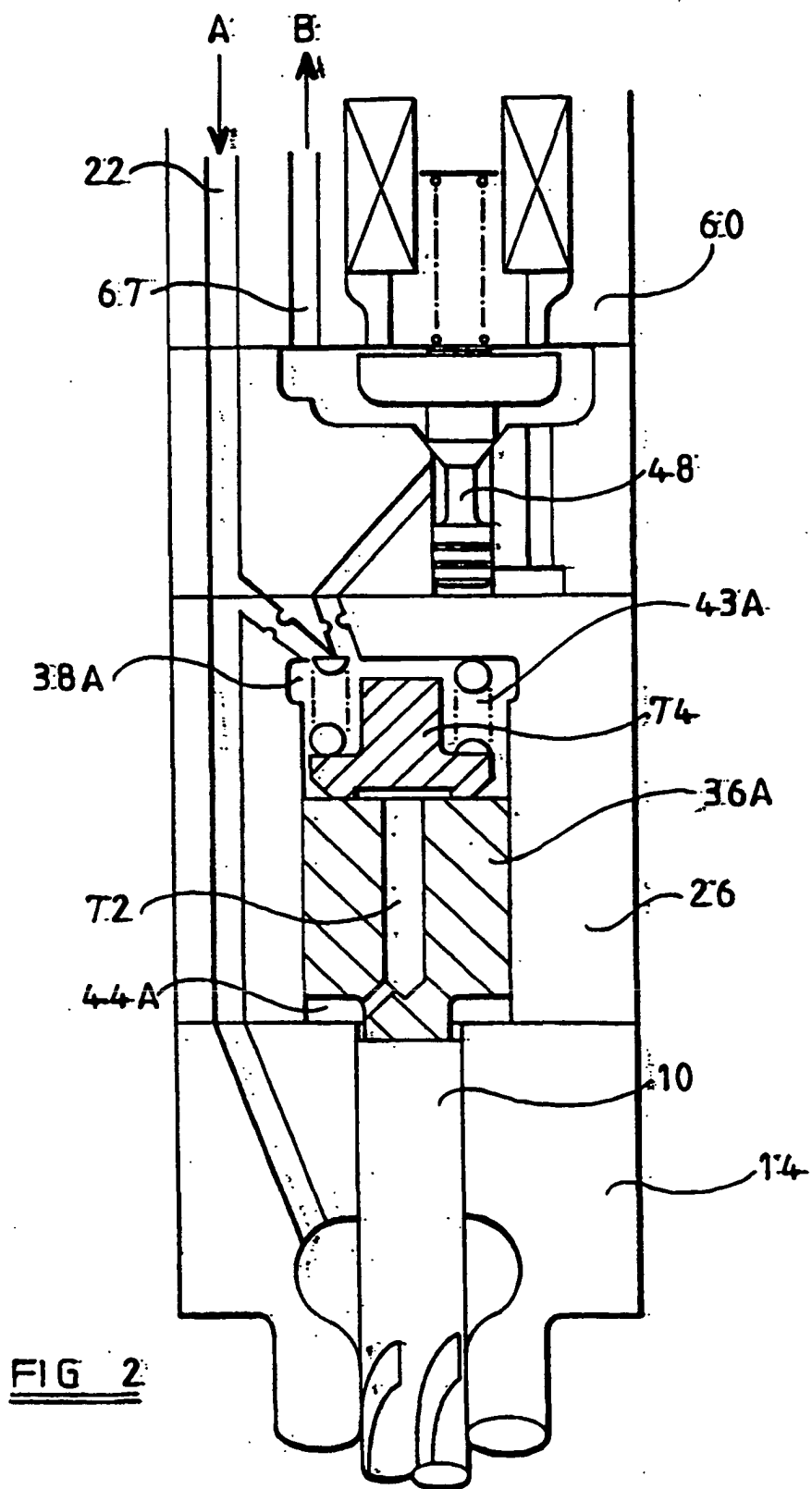
6. Injecteur de carburant selon la revendication 5, dans lequel la soupape sphérique (83) comprend un ressort de sollicitation pour solliciter la soupape sphérique dans la position fermée lorsque la pression de carburant à l'intérieur de la chambre intermédiaire (44F) est réduite suffisamment, durant l'utilisation. 5
7. Injecteur de carburant selon l'une quelconque des revendications 1 à 6, dans lequel les moyens de soupape (83, 86) sont agencés à l'intérieur du passage de déversement (81). 10
8. Injecteur de carburant selon la revendication 7, dans lequel le passage de débit limité (90, 90a) ne communique pas directement avec le passage de déversement (81) de sorte que le fonctionnement des moyens de soupape (83) n'est sensiblement pas affecté, durant l'utilisation, par le passage de carburant à travers le passage de débit limité (90, 90a). 15 20
9. Injecteur de carburant selon l'une quelconque des revendications 1 à 8, comprenant en outre des moyens de sollicitation résilients (43, 43a) sollicitant l'élément de piston (36) vers le pointeau de soupape (10). 25
10. Injecteur de carburant selon la revendication 9, dans lequel les moyens de sollicitation résilients (43, 43a) sont agencés à l'intérieur de la chambre intermédiaire (44F) ou à l'intérieur de la chambre de commande (38F). 30
11. Injecteur de carburant selon l'une quelconque des revendications 1 à 10, dans lequel le pointeau de soupape (10) a une surface utile plus importante pouvant être exposée à la pression de carburant à l'intérieur de la chambre intermédiaire (44F) que la surface utile de la surface ou des surfaces de poussée. 35 40

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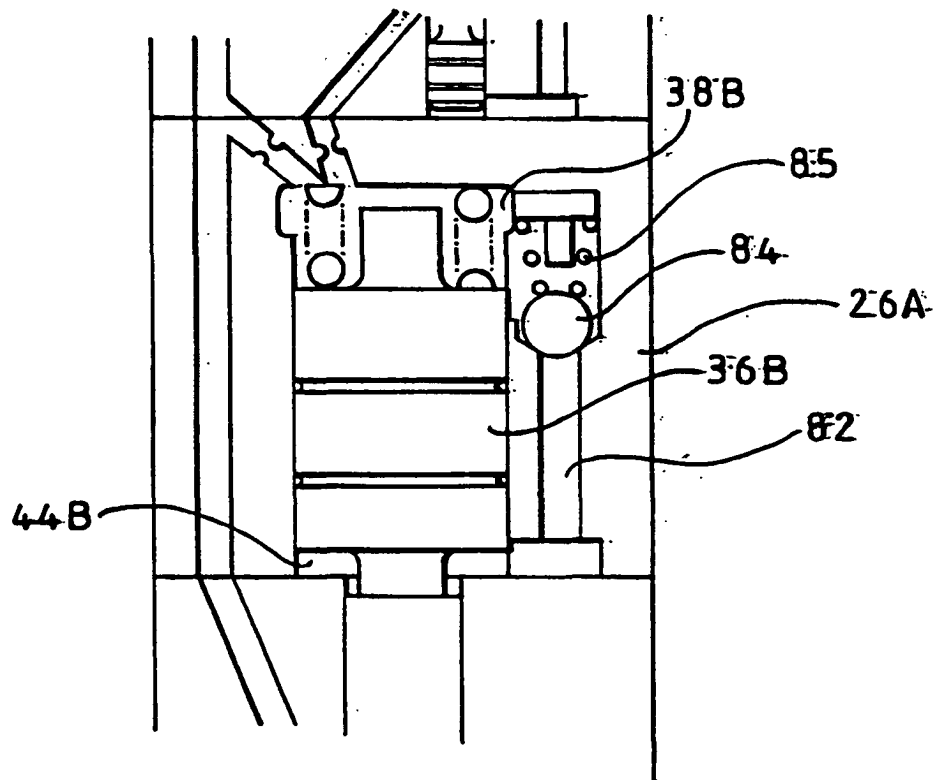


FIG 3

