(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 505 294 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
09.02.2005 Bulletin 2005/06

(51) Int Cl.7: **F02M 45/06**, F02M 57/02, F02M 59/34

(21) Application number: **03254935.4**

(22) Date of filing: **07.08.2003**

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IT LI LU MC NL PT RO SE SI SK TR
Designated Extension States:
AL LT LV MK

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

(72) Inventor: **Felton, Nicholas**
Gillingham, Kent ME8 0HD (GB)

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

(54) **Pump assembly**

(57) A pump assembly for use in a compression ignition engine includes a plunger (2) that is reciprocable within a plunger housing (6) to pressurise fuel within a compression chamber (8). A first flow path (22) provides communication between the compression chamber (8) and a low pressure circuit (26, 28) to permit filling of the compression chamber (8), and is closed to fuel flow to initiate pressurisation of fuel within the compression chamber (8). A second flow path (40, 42) provides communication between the compression chamber (8) and the low pressure circuit (26, 28), and is opened to fuel flow to terminate pressurisation of fuel within the compression chamber after said closure the first flow path (22). The second flow path (40, 42) is provided with flow restriction means (44) to retard the rate of depressurisation of the compression chamber (8).

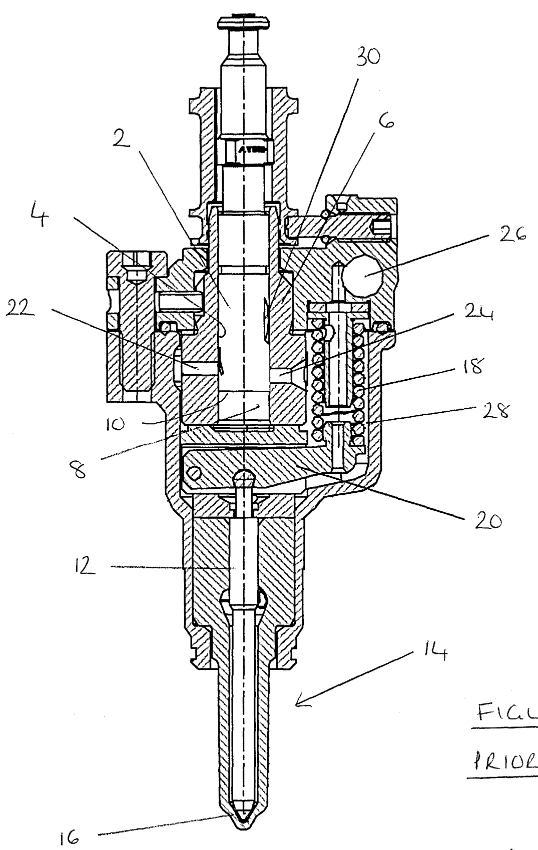

FIGURE 1

PRIOR ART

EP 1 505 294 A1

Description

[0001] This invention relates to a pump assembly and, in particular, to a pump assembly for use in compression ignition engines.

[0002] Known fuel injection systems for supplying fuel to the cylinders of a compression ignition engine include a fuel injection pump, or pump assembly, for generating injection pressure and for delivering fuel at injection pressure to the injection nozzles of the system via high-pressure fuel lines.

[0003] In one type of fuel injection system, known as the unit injector, a pump assembly and a dedicated injection nozzle are arranged together within a common unit. The unit injector is usually driven by a camshaft run off the engine via a cam drive arrangement.

[0004] Figure 1 is an example of a known unit injector design, in which a plunger 2 reciprocates within a plunger bore 4 formed in a plunger housing or barrel 6. A pump or compression chamber 8 is defined by an end face 10 of the plunger 2 and the blind end of the plunger bore 4. A valve needle 12 of an injection nozzle 14 is responsive to the pressure of fuel supplied from the pump chamber 8 to the nozzle 14 and is biased closed against a valve needle seat 16 by means of a spring 18. In this particular unit injector the spring 18 acts on the valve needle 12 through a rocker arm 20, although other unit injector designs have the spring 18 axially aligned with the needle 12 at its pump chamber end.

[0005] First and second ports, 22 and 24 respectively, are provided in the plunger barrel 6 to provide a flow path for fuel into and out of the pump chamber 8 from a low pressure source 26 (via a storage space 28), depending on the position of the plunger 2 within its bore 4.

[0006] The plunger 2 is provided with a slot formation including two slots which are cut into its outer surface: a first longitudinal slot (not visible in Figure 1) which cuts through the end face 10 of the plunger 2 (referred to as a "stop slot"), and a second helical slot 30 which is cut at an angle to the stop slot and is arranged to communicate at one end with the stop slot.

[0007] The plunger 2 is driven by a cam drive to perform a pumping cycle during which fuel within the chamber 8 is pressurised to initiate an injection event and subsequently depressurised to terminate injection. The provision of the helical groove 30 is the means by which the quantity of fuel injected is controlled. During a forward stroke of the plunger (from bottom-dead-centre (BDC) to top-dead-centre (TDC)), pressurisation of fuel within the chamber 8 occurs when the plunger 2 has closed both ports 22, 24 and up until the point at which the edge of the helical groove 30 aligns with the second port 24 to permit fuel to escape to low pressure. As fuel within the pump chamber 8 is pressurised, the valve needle 12 is caused to lift from its seating 16 to commence injection. At the point at which the edge of the helical groove is aligned with the port 24, the pressure of fuel within the pump chamber 8 decays rapidly as fuel escapes through the helical groove 30 and the port 24 to low pressure, thereby causing the valve needle 12 to reseat to terminate injection. The rate of pressure collapse in the pump chamber 8 at termination of injection is relatively rapid, and so the valve needle 12 is caused to seat quickly.

[0008] For some applications it is desirable for the rate of pressure collapse to be reduced or controlled carefully. In a modification of the unit injector in Figure 1, it is known to provide an additional spring-biased plate valve for this purpose. The plate valve is provided with a restricted orifice and is housed within an adapter plate located between the barrel 6 and the associated nozzle 14 (referring to Figure 1), within the high pressure connection between the pump chamber 8 and the nozzle 14. Upon termination of injection (i.e. with fuel pressure within the pump chamber decreasing), the plate valve is urged against its seating and the rate at which fuel can flow from the nozzle to low pressure is restricted by the orifice to reduce the rate of pressure collapse in the pump chamber. This is a satisfactory solution for some applications, although the requirement for additional moving parts (the plate valve and associated spring) adds cost and complexity to the unit. To some extent, the plate valve also influences initiation of injection as the closing force of the plate valve spring must be overcome before an unrestricted flow of high pressure fuel is able to flow to the nozzle.

[0009] It is with a view to providing improvements to the above-mentioned prior art that the following is presented.

[0010] According to a first aspect of the invention, there is provided a pump assembly for use in a compression ignition engine, the pump assembly comprising:

> a plunger which is reciprocal within a plunger housing, in use, to pressurise fuel within a compression chamber,
>
> a first flow path providing communication between the compression chamber and a low pressure circuit to permit filling of the compression chamber, and being closed to fuel flow to initiate pressurisation of fuel within the compression chamber,
>
> a second flow path providing communication between the compression chamber and the low pressure circuit, and being open to fuel flow to terminate pressurisation of fuel within the compression chamber after closure of the first flow path,

wherein the second flow path is provided with flow restriction means to restrict the rate of flow of fuel to the low pressure circuit at the end of pressurisation.

[0011] Where the pump assembly is of the type for supplying pressurised fuel to an injection nozzle to initiate injection, the invention provides the advantage that the rate of pressure collapse within the pump chamber to terminate injection is reduced. The valve needle of the nozzle therefore experiences a cushioning effect as it seats, reducing wear and prolonging service life. The effects of gas blow-by are also reduced. It is a particular advantage that the invention achieves these benefits without the requirement to provide additional or moving parts in known pump assembly designs, such as unit injectors or unit pumps.

[0012] A further beneficial feature of the invention is that the supply of high pressure fuel to the associated nozzle is not affected by the provision of the flow restriction means, which only influences the rate of depressurisation of the compression chamber. Thus, a passage for high pressure fuel between the compression chamber and the nozzle is provided which permits fuel flow to and from an associated injection nozzle at a substantially unrestricted rate.

[0013] In one preferred embodiment, for example, the second flow path is at least partially provided in a portion of the plunger housing itself and the flow restriction means is provided within said portion of the plunger housing.

[0014] Alternatively, the second flow path may be at least partially provided in a portion of the plunger and the flow restriction means is provided within said portion of the plunger.

[0015] Advantageously, said portion of the second flow path may include a passageway or drilling along an axis substantially parallel to a first longitudinal axis of the plunger, and said flow restriction means is provided along this passageway.

[0016] Alternatively, said portion of the second flow path may include a passageway or drilling along an axis substantially perpendicular or transverse to the longitudinal axis of the plunger, and said flow restriction means is provided along this passageway.

[0017] It is preferable that the plunger housing comprises a plunger bore within which the plunger is reciprocable, with plunger motion being guided directly by an inner wall of the plunger bore.

[0018] Advantageously, the first flow path comprises a filling port provided in the housing and opening to the plunger bore.

[0019] The second flow path may include a second port provided in the plunger housing and opening to the plunger bore, wherein the second port is provided with the flow restriction means (as mentioned above).

[0020] In one embodiment, the pump assembly is a fuel pump (for example, a unit pump) for supplying pressurised fuel to a dedicated injector remote from the pump assembly, in use.

[0021] Alternatively, the pump assembly may be a unit injector, also comprising an injector arranged within a common unit with the pump assembly.

[0022] A second aspect of the invention relates to a plunger suitable for use with any of the aforementioned pump assemblies, characterised in that the plunger comprises a passageway along which is provided said flow restriction means.

[0023] In this context, the pump assembly unit of the invention may be incorporated into a unit pump, in which a dedicated injector is arranged remote from the pump assembly, a unit injector where the pump assembly and dedicated injector/injection nozzle are arranged in a common housing to form a single unit or any other kind of pump unit for supplying pressurised fuel to a dedicated injection nozzle/injector.

[0024] It will therefore be appreciated that the phrase "unit pump assembly" is intended to include reference to unit pumps and unit injectors, and the like.

[0025] The present invention is now described with reference to the accompanying figures wherein:

Figure 1 is a schematic view of a known unit injector;

Figure 2 is a sectional view of a unit injector according to a first embodiment of the invention; and

Figure 3 is a detailed view of part of the unit injector mechanism shown in Figure 2.

[0026] Referring to Figures 2 and 3, a pump assembly of one embodiment of the present invention takes the form of a unit injector having many similar features to the prior art unit injector described previously. Where possible, similar parts to those shown in Figure 1 will be referred to with like reference numerals.

[0027] The plunger 2 is reciprocal within a plunger bore 4 provided in a plunger housing or barrel 6, with the plunger end face 10 defining the pump or compression chamber 8 at the blind end of the bore 4. The associated injection nozzle 14 includes a valve needle 12 provided with thrust surfaces (not identified), which are exposed to fuel pressure within a delivery chamber 32 defined within a nozzle bore 34. The delivery chamber 32 communicates with the pump chamber 8 of the pump assembly through channels which are not visible in the sections shown in Figures 2 and 3. The nozzle 14 is provided with nozzle spray holes (not shown) through which pressurised fuel is delivered to an associated engine cylinder when the valve needle 12 is caused to lift from its seating. The injection nozzle 14 and a lower end of the plunger housing 6 are retained between first and second housings 36, 38 respectively in a conventional manner.

[0028] First and second ports 22, 24 respectively are provided in the plunger housing 6 to open to the plunger bore 4, as described previously. A low pressure circuit including a storage space 28 and a supply rail 26 (typically at a pressure of 4 bar) is able to communicate with the pump chamber 8 through one or both of the first and second ports 22, 24 when they are open. Whether the ports 22, 24 are open or closed depends on the position of the plunger 2 within the bore 4.

[0029] Both the first and second ports 22, 24 provide a flow path by which the pump chamber 8 is filled during the pumping cycle. Notably, the unit injector shown in Figures 2 and 3 and the prior are unit injector in Figure 1 differ in the means by which the pump chamber 8 is brought into communication with the low pressure circuit 26, 28 at the end of an injection event. The distinctive feature of Figures 2 and 3, and that which distinguishes the invention from prior art assemblies, is shown in the highlighted portion X of Figure 2 and is reproduced in greater detail in Figure 3.

[0030] Referring in particular to Figure 3, the plunger 2 is provided with two additional drillings or passageways 40, 42 forming flow paths within the plunger 2. The drillings 40, 42 are provided instead of the stop slot in the pump assembly of Figure 1. A first longitudinal drilling 40 cuts through the plunger end face 10, preferably along the longitudinal axis of the plunger 2 for ease of manufacture, and meets with a second transverse drilling 42, perpendicular to the plunger axis, through a restriction 44. Much in the same way as in Figure 1, a helical groove or slot 30 is also provided in the plunger surface, only a portion of which is visible in Figure 3. The transverse drilling 42 is able to communicate with the second port 24 through the helical groove 30. The longitudinal drilling 40, the restriction 44, the transverse drilling 42 and the helical groove 30 together define a fuel flow path, having restricted flow means 44, by which the pump chamber 8 is able to communicate with the storage space 28 and the low pressure fuel rail 26. Typically, for example, the restriction is of the order of 1.0-1.5 mm diameter.

[0031] As an aside, it is preferable (although inessential) to provide the plunger 2 with a circumferential leakage groove 46, which serves to collect leakage fuel down the plunger bore 4 from the pump chamber 8. A further port 48 in the plunger housing 6 enables fuel collected within the leakage groove 46 to flow into the storage space 28 and to the low pressure rail 26. Other means for providing leakage collection are also envisaged, for example the plunger bore 4 may be provided with a leakage groove instead.

[0032] The pump assembly in Figures 2 and 3 has a similar pumping cycle to that described previously for the prior art, but its operation will now be described in detail to emphasise the functional advantages it provides.

[0033] In use, the plunger 2 is driven by the engine-driven cam to perform a pumping cycle having two extreme positions of motion. At top dead centre (TDC) the plunger 2 is at the innermost position within the bore 4 and at bottom dead centre (BDC) the plunger 2 is at the outermost position within the bore 4.

From a starting position of TDC, the pumping chamber 8 is at its minimum volume and the end of the helical groove 30 is at least partially aligned with the second port 24. As the plunger 2 begins to travel towards BDC (referred to as the plunger return stroke), the pump chamber volume is expanding and a point will be reached at which the plunger end face 10 passes the edge of the first port 22 causing a substantially unrestricted flow of fuel to be drawn into the pump chamber 8 from the low pressure rail 26. As the plunger 2 continues to move towards BDC, the plunger end face 10 clears the lowermost edge of the second port 24 also so that further fuel is admitted into the pump chamber 8 through the second port 24.

[0034] Once the plunger 2 reaches BDC, the pump chamber 8 is at its maximum volume and filled with fuel. As the plunger 2 starts to move towards TDC (referred to as the plunger forward stroke), the volume of the pump chamber 8 starts to decrease and, initially, fuel is dispelled from the pump chamber 8 to the low pressure circuit 26, 28 through the uncovered ports 22, 24. As the plunger 2 moves further through the forward stroke, the end face 10 clears, initially, the lowermost edge of the second port 24 and subsequently the lowermost edge of the first port 22. Fuel remaining in the pump chamber 8, with the first and second ports 22, 24 closed by the plunger 2, will undergo pressurisation as the plunger 2 moves further through the forward stroke. It will be appreciated that pressurisation of fuel within the pump chamber 8 is only initiated when the first port 22 is also closed to break all communication routes between the pump chamber 8 and the low pressure rail 26.

[0035] Pressurised fuel within the pump chamber 8 is delivered to the delivery chamber 32 of the nozzle 14 through channels and passages of the pump and nozzle assembly (not shown) and a point will be reached at which the force due to the shut-off spring 18 is overcome and the needle 12 lifts from its seating 16. Under such circumstances fuel flows out of the nozzle holes into the engine cylinder to commence injection. It will be appreciated that this flow of high pressure fuel to the nozzle 14 is not restricted, and in particular the provision of the restricted drilling 44 has no bearing on this flow of fuel.

[0036] As the plunger 2 moves further through the forward stoke, a point will be reached at which the lowermost edge of the helical groove 30 passes the uppermost edge of the second port 24. As the plunger 2 moves further through the forward stroke, fuel within the pump chamber 8 is therefore able to flow through the longitudinal drilling 40, into the restriction 44, through the transverse drilling 42, into the helical groove 30 and into the second port 24 to low pressure. Fuel pressure within the pump chamber 8 is therefore reduced, or collapses, at a rate determined by the size of the restriction 44. The longitudinal drilling 40, the restriction 44, the transverse drilling 42 and the second port 24 therefore form part of a restricted flow passage for fuel between the pump chamber 8 and the low pressure circuit 26, 28.

[0037] As the pressure of fuel being supplied to the delivery chamber 32 of the nozzle 14 is reduced, a point will be reached at which the force due to the spring 18 is sufficient to re-seat the valve needle 12, thereby terminating injection through the nozzle holes. For the remainder of the plunger forward stroke, the plunger 2 moves to fully align the helical groove 30 with the second port 24, and may move beyond this point although at all times ensuring the flow passage to low pressure through the drillings 40, 44, 42, the groove 30 and the second port 24 is maintained.

[0038] During the subsequent plunger return stroke the plunger 2 moves outwardly from the bore 4, expanding the volume of the pump chamber 8 and filling the pump chamber 8 through the first and second ports 22, 24 ready for the next forward stroke, as described previously.

[0039] It is an important feature of the present invention that the rate of pressure collapse at the end of injection is controlled, or reduced, due to the provision of the restriction 44 in the plunger 2. By reducing the rate of pressure collapse at the end of injection, fuel suck-back through the nozzle holes, nozzle passageways and the pump chamber 8 is slowed, resulting in fuel remaining in the region of the valve needle seating 16 for a slightly longer period so as to cushion the valve needle 12 during the seating process. It is a benefit of this that valve needle and needle seat wear is reduced.

[0040] The provision of the restriction 44 within the plunger 2 itself is easy to accommodate and requires no additional parts to those in existing units. The jet of high pressure fuel expelled from the restriction 44 also impinges an internal surface of the plunger 2, which being made from a hard wearing material does not wear significantly as a result.

[0041] It is a further benefit of the invention that the detrimental effects of gas blow-by are minimised. Gas blow-by is known to occur in injection nozzles generally, due to combustion gasses being sucked from the combustion cylinder up into the nozzle, and can result in blocked flow passageways and contamination of the fuel system. Reducing the rate of pressure collapse in the pump chamber 8 at the end of injection minimises these effects.

[0042] As is known in unit injectors generally of the aforementioned type, the plunger 2 is movable angularly about its longitudinal axis so that the point in the forward stroke at which the edge of the helical groove 30 is brought into communication with the second port 24 may be adjusted. Hence, the quantity of fuel that is injected during each pumping cycle can be controlled by adjusting the angular position of the plunger 2.

[0043] It is noted that the helical groove 30 necessarily does not cut through to the plunger end face 10, otherwise depressurising fuel would flow through the helical slot, bypassing the longitudinal drilling 40 and through the restriction 44. Were this to happen the benefits of the restriction 44 in controlling fuel pressure collapse would not be realised.

[0044] Although the embodiment described shows a restriction 44 between two drillings 40, 42, it is to be noted that the invention does not preclude location of the restriction along other positions in the fuel depressurisation circuit to achieve the same benefits as those described above. As an example, an alternative location for the restriction would be in the transverse drilling 42, although this embodiment may be less preferable as the depressurising fuel jet may impinge on other parts of the pump assembly, and not on internal surfaces of the plunger 2.

[0045] Another embodiment provides one of the ports 22, 24 with a restriction whilst the other is unrestricted. The ports must be positioned so that pump chamber filling can occur through the unrestricted port, whilst depressurisation of the pump chamber 8 occurs through the restricted port. In this embodiment the plunger housing 6 of existing units therefore requires modification, and the plunger 2 also requires the provision of the drillings 40, 42 (with no stop slot).

Claims

1. A pump assembly for use in a compression ignition engine, the pump assembly comprising:

   a plunger (2) that is reciprocable within a plunger housing (6) to pressurise fuel within a compression chamber (8),
   a first flow path (22) providing communication between the compression chamber (8) and a low pressure circuit (26, 28) to permit filling of the compression chamber (8), and being closed to fuel flow to initiate pressurisation of fuel within the compression chamber (8),
   a second flow path (40, 42, 24) providing communication between the compression chamber (8) and the low pressure circuit (26, 28), and being opened to fuel flow to terminate pressurisation of fuel within the compression chamber after said closure the first flow path (22);

   characterised in that:

   the second flow path (40, 42, 24) is provided with flow restriction means (44) to retard the rate of depressurisation of the compression chamber (8).

2. A pump assembly according to Claim 1, further **characterised in that** the second flow path (40, 42, 24) is at least partially provided in a portion of the plunger housing (6) and the flow restriction means is provided within said portion.

3. A pump assembly according to Claim 1, further **characterised in that** the second flow path (40, 42, 24) is at least partially provided in a portion of the plunger (2) and the flow restriction means (44) is provided within said portion.

4. A pump assembly according to Claim 3, further

characterised in that said portion of the second flow path comprises a drilling (40) along an axis parallel with a longitudinal axis of the plunger (2), and said flow restriction means (44) is provided along the drilling (40).

5. A pump assembly according to Claim 3, further **characterised in that** said portion of the second flow path comprises a drilling (42) along an axis transverse to a longitudinal axis of the plunger (2) and said flow restriction means is provided along the drilling (42).

6. A pump assembly according to any one of the preceding claims, further **characterised in that** the plunger housing (6) is provided with a plunger bore (4), which serves to guide reciprocal motion of the plunger (2) within the plunger housing (6).

7. A pump assembly according to any one of the preceding claims, wherein the first flow path comprises a filling port (22) provided in the plunger housing (6) and opening to the plunger bore (4).

8. A pump assembly according to any one of claims 1 to 7, in the form of a fuel pump for supplying pressurised fuel to a dedicated injector remote from the pump assembly, in use.

9. A pump assembly according to any one of claims 1 to 7, in the form of a unit injector, which also comprises an injection nozzle (14) arranged within a common unit with the pump assembly (2, 6).

10. A pump assembly as claimed in claim 9, including a passage for high pressure fuel between the compression chamber (8) and the nozzle (14), which permits fuel flow to and from the injection nozzle (14) at a substantially unrestricted rate.

11. A plunger (2) suitable for use with any one of the preceding claims,
characterised in that the plunger (2) comprises a fuel flow passage (40, 42) along which is provided restriction flow means (44).

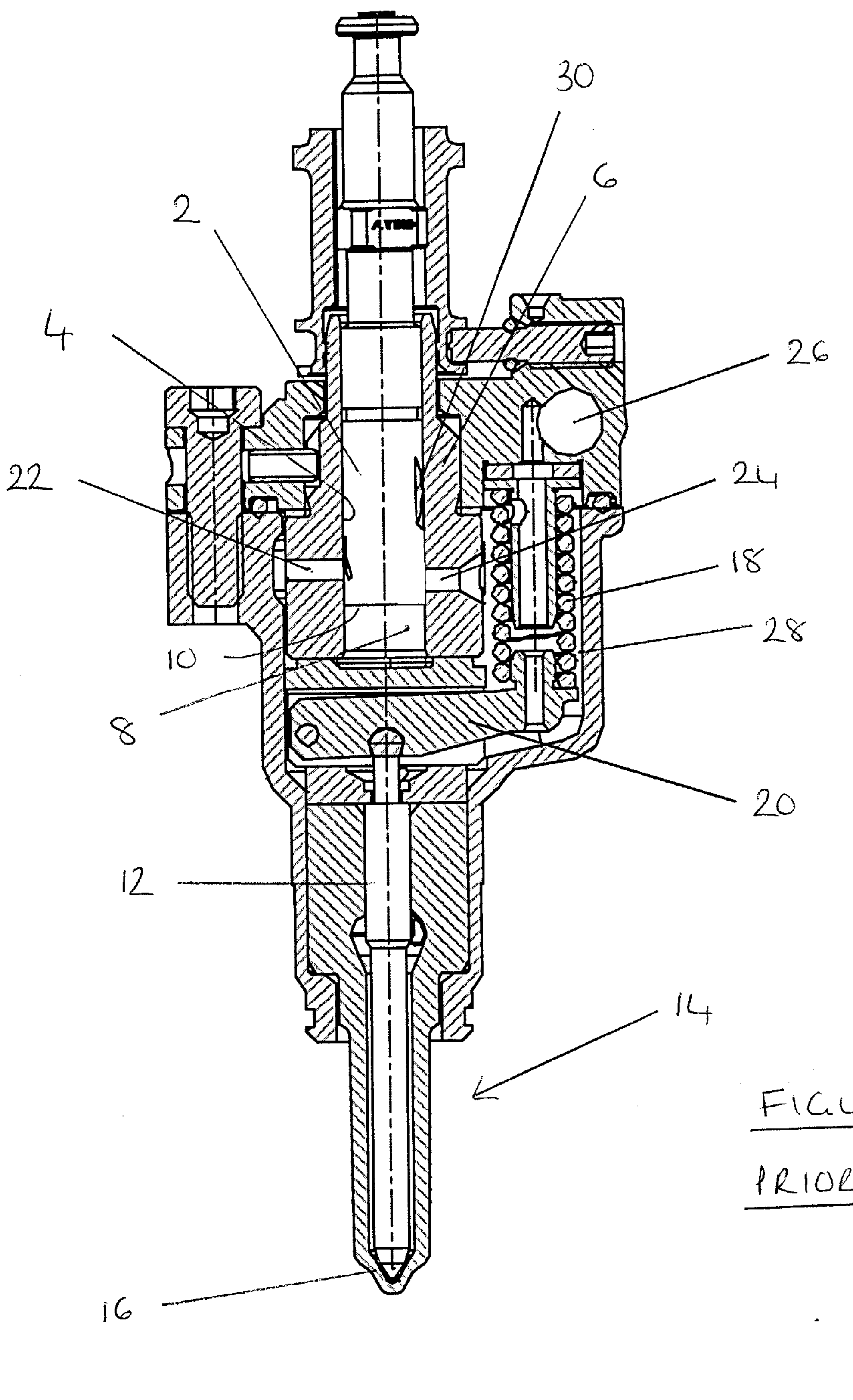

FIGURE 1

PRIOR ART

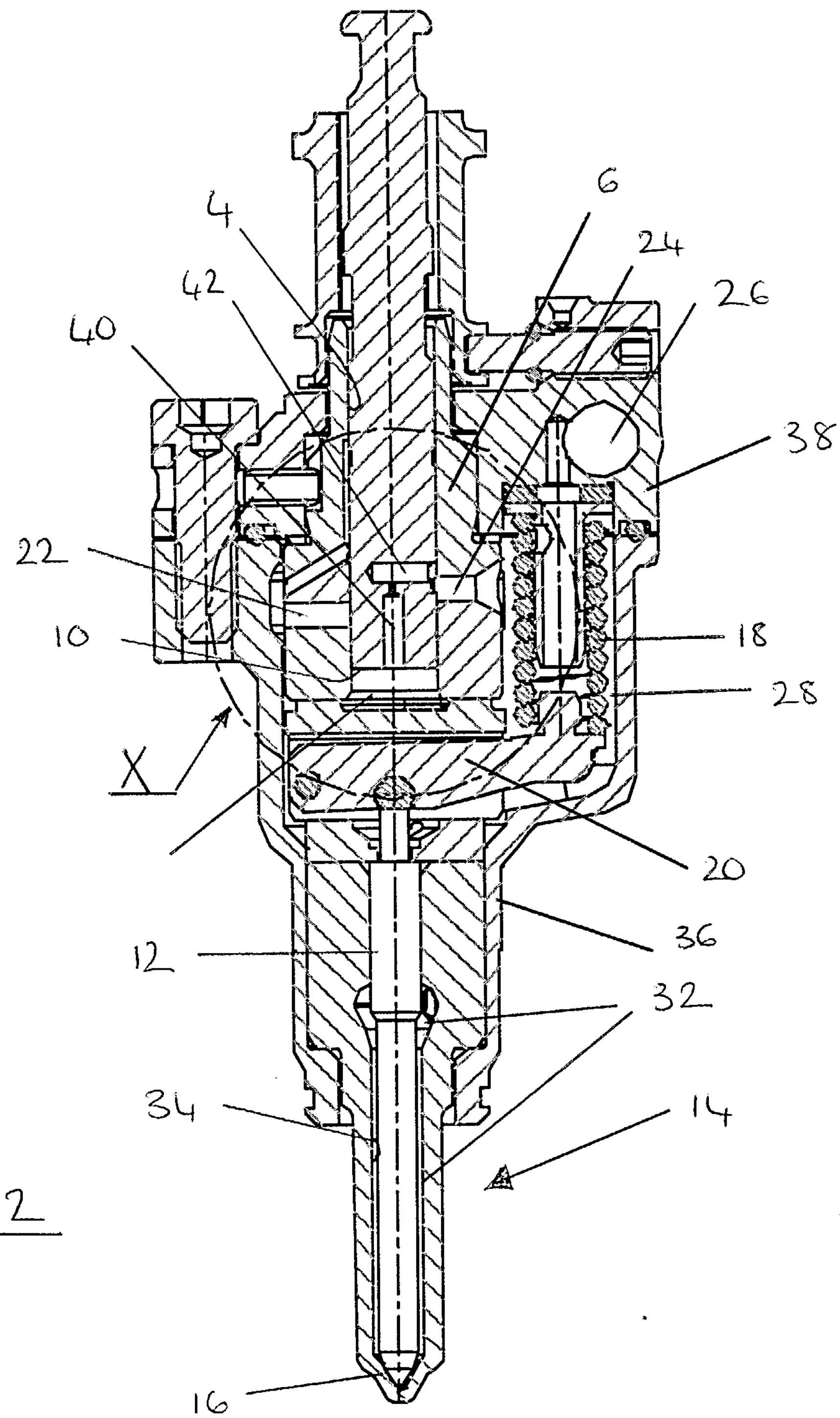

FIGURE 2

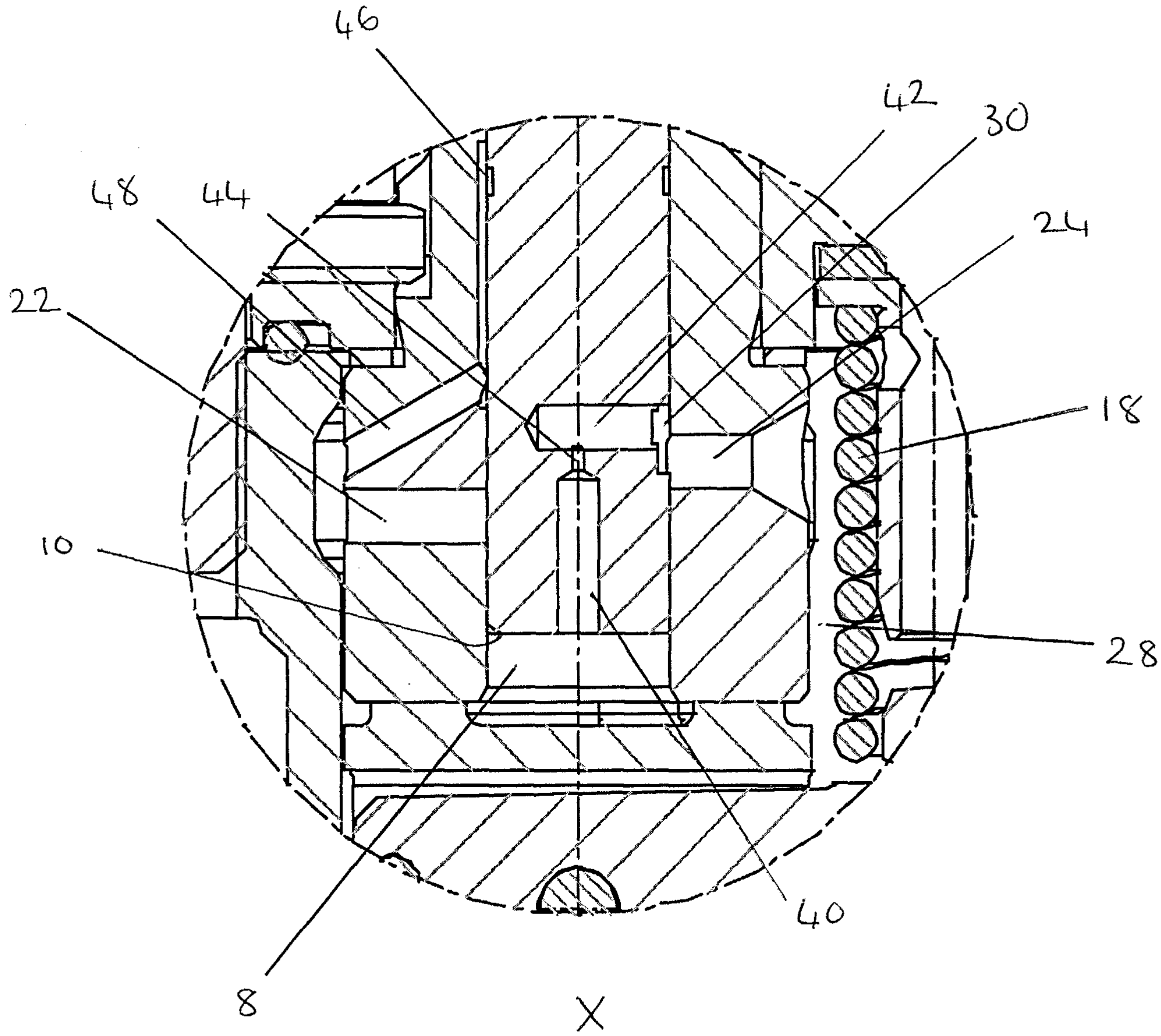

FIGURE 3

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 03 25 4935

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
X	US 2002/092920 A1 (AUGUSTIN ULRICH) 18 July 2002 (2002-07-18) * paragraphs [0030],[0031]; figures 1,5,6 *	1,3-7, 9-11	F02M45/06 F02M57/02 F02M59/34
X	FR 2 564 900 A (MASCHF AUGSBURG NUERNBERG AG) 29 November 1985 (1985-11-29) * page 7, line 33 - page 9, line 7 * * page 11, line 21 - page 13, line 4; figures 1,6,7 *	1,2,6-8, 10	
X	US 6 012 429 A (SMITH III RALPH A ET AL) 11 January 2000 (2000-01-11) * column 5, line 34 - line 51; figure 9 *	1,2,6,7, 9,10	

TECHNICAL FIELDS SEARCHED (Int.Cl.7)
F02M

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
MUNICH	16 December 2003	Kolland, U

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 03 25 4935

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

16-12-2003

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
US 2002092920	A1	18-07-2002	NONE			
FR 2564900	A	29-11-1985	DE	3419167	A1	28-11-1985
			ES	8607480	A1	01-11-1986
			FI	851958	A	24-11-1985
			FR	2564900	A1	29-11-1985
			JP	60256554	A	18-12-1985
			NL	8501453	A	16-12-1985
US 6012429	A	11-01-2000	FR	2755188	A1	30-04-1998
			GB	2318619	A ,B	29-04-1998

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82