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(71) Applicant: **Delphi International Operations Luxembourg S.à r.l.**  
**4940 Bascharage (LU)**

(72) Inventors:  

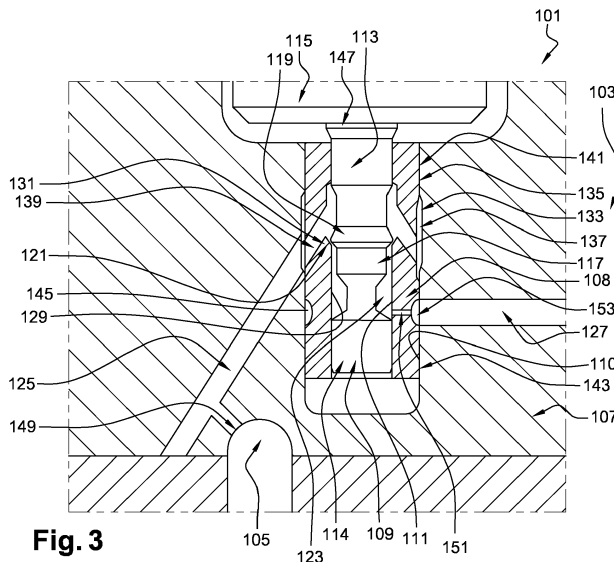
- **THIBAUT, Thierry**  
**37530 Saint Ouen les Vignes (FR)**
- **BALIN, Marion**  
**41150 Onzain (FR)**

(74) Representative: **Neill, Andrew Peter**  
**Delphi Diesel Systems**  
**Patent Department**  
**Courteney Road**  
**Gillingham, Kent ME8 0RU (GB)**

(54) **CONTROL VALVE**

(57) The present disclosure relates to a fuel injector (101, 201) for injecting fuel into a combustion chamber of an internal combustion engine. The fuel injector (101, 201) comprises a control chamber (105) for controlling a needle valve. A control valve assembly (103) is provided for controlling fuel pressure within the control chamber (105). A fuel return line (127) is provided for returning fuel from the control valve assembly (103). The control valve assembly (103) has a control valve (119) and a valve seat (121). The control valve (119) is movable between a closed position in which fluid communication is

inhibited between the control chamber (105) and the fuel return line (127) and an open position in which fluid communication is enabled between the control chamber (105) and the fuel return line (127). A fuel flow restriction (151, 251) is provided downstream of the valve seat (121) for maintaining the fuel pressure in a region between the valve seat (121) and the fuel flow restriction (151, 251) above a return pressure of fuel in the fuel return line (127). The present disclosure also relates to a control valve assembly (103) for a fuel injector (101, 201).



**Fig. 3**

## Description

### TECHNICAL FIELD

**[0001]** The present disclosure relates to a control valve assembly for a fuel injector; and to a fuel injector.

### BACKGROUND

**[0002]** It is known to control the operation of a fuel injector 1 using a control valve assembly 3 to control fuel pressure within a control chamber 5. A sectional view of a known control valve assembly 3 is schematically represented in Figure 1. The fuel pressure within the control chamber 5 acts upon a surface associated with a needle valve (not shown) of the injector to apply a force to the needle valve urging the needle valve towards a needle seating. The control valve assembly 3 comprises a valve housing 7 which is provided with a bore 9 within which a valve stem 11 is movable. The valve stem 11 includes a control valve 13 which is engageable with a valve seat 15 defined around an upper end 17 of the bore 9. The valve stem 11 is movable between a closed position in which the control valve 13 is seated in the valve seat 15, and an open position in which the control valve 13 is lifted from the valve seat 15. The control chamber 5 communicates through a control line 19 with a chamber 21 defined between a region 23 of the valve stem 11 of reduced diameter and the bore 9 within which the valve stem 11 is movable. When the valve stem 11 is moved to the open position, a volume of fuel, which is required to maintain a pressurised environment within the control chamber 5, flows past the control valve 13. The fuel exits the fuel injector 1 through a return line (not shown) downstream of the control valve 13. The fuel flows out of the fuel injector 1 via an outlet of the return line, where it is subsequently directed to a reservoir for re-use in a subsequent injection cycle.

**[0003]** In order to control the operation of the needle valve, it is known to restrict the flow rate of fuel flowing from the control chamber 5. To this effect, a fuel flow restriction 25 is provided at an outlet 27 of the control chamber 5, upstream of the control line 19.

**[0004]** When the control valve 13 is moved to the open position, fluid communication is allowed between the control chamber 5 and the fuel return line. The fuel pressure within the control chamber 5 decreases as the fuel flows from the control chamber 5 into the control line 19. The fuel flow restriction 25 restricts the flow rate of fuel into the control line 19, creating a first pressure drop between the control chamber 5 and the control line 19 when the control valve 13 is moved to the open position. As represented in Figure 2, fuel upstream of the fuel flow restriction 25 is at a pressure of approximately 2500 bars, whereas fuel downstream of the fuel flow restriction 25 and upstream of the control valve 13 is at a pressure of approximately 200 bars. A second pressure drop occurs across the restriction when the control valve 13 lifts from

the valve seat 15. The second pressure drop is from approximately 200 bars upstream of the valve seat 15 to approximately 5 bars downstream of the valve seat 15. At valve closure, the inertia of the fuel may create a localized region of very low pressure proximal to the valve seat 15 which can induce cavitation in the fuel (i.e. vapour cavities form in the fuel). It is believed that cavitation in the fuel may result in damage to the valve seat 15. Any such damage may affect performance of the fuel injector 1.

**[0005]** At least in certain embodiments, the present invention sets out to overcome or ameliorate at least some of the problems associated with known fuel injectors.

### 15 SUMMARY OF THE INVENTION

**[0006]** Aspects of the present invention relate to a control valve assembly for a fuel injector; and to a fuel injector.

**[0007]** According to a further aspect of the present invention, there is provided a control valve assembly for controlling fuel pressure within a control chamber of a fuel injector, the control valve assembly comprising:

- 25 a control valve;
- a valve seat;
- a fuel control line for connection to the control chamber; and
- 30 a fuel return line;
- the control valve being movable between a closed position for inhibiting fluid communication between the fuel control line and the fuel return line and an open position for enabling fluid communication between the fuel control line and the fuel return line;
- 35 wherein a fuel flow restriction is provided downstream of the valve seat for maintaining the fuel pressure in a region between the valve seat and the fuel flow restriction above a return pressure of fuel in the fuel return line. The fuel flow restriction is provided downstream of the valve seat such that, in use, the flow of fuel into or through the fuel return line is restricted. The fuel flow restriction thereby maintains the fuel pressure in said region between the valve seat and the fuel flow restriction above the fuel return pressure. The fuel return pressure refers herein to the pressure of the fuel downstream of the fuel flow restriction at which the fuel is returned in the fuel return line. It has been recognised by the inventors that cavitation can be reduced by maintaining a higher fuel pressure. Thus, providing the fuel flow restriction to maintain the fuel at an elevated pressure can reduce or prevent cavitation in the fuel at or proximate to the valve seat. Thus, when the control valve is moved to the closed position, the formation of vapour cavities in the fuel can be reduced or prevented. At least in certain embodiments, damage to the valve seat may be reduced, thereby helping to maintain performance of the control valve assembly.

**[0008]** The fuel flow restriction can be adapted such that, in use, the fuel pressure in said region between the valve seat and the fuel flow restriction is greater than or equal to 1000 bars, 1500 bars, 2000 bars or 2300 bars. This fuel pressure can represent a mean operating pressure or a peak operating pressure of the fuel in the region between the valve seat and the fuel flow restriction. The fuel flow restriction can be configured such that, in use, the fuel pressure proximate to the valve seat can remain significantly above a vapour pressure of the fuel. The fuel flow restriction can be configured to maintain the fuel pressure in the region between the valve seat and the fuel flow restriction sufficiently high to ensure that, in use, the localized low pressure region established when the control valve is moved to said closed position always remains at a pressure greater than a vapour pressure of the fuel. By way of reference, the vapour pressure of diesel fuel is approximately 1 mbar at 20°C.

**[0009]** The fuel flow restriction can be in the form of a fuel flow restrictor. The fuel flow restrictor can, for example, have a diameter of between 0.1 mm and 0.5mm (inclusive). More particularly, the fuel flow restrictor can have a diameter of between 0.2mm and 0.4mm (inclusive). The fuel flow restrictor can have a length of between 0.3mm to 0.7mm (inclusive). The fuel flow restriction can be configured depending on the operating parameters of the fuel injector.

**[0010]** When the control valve is in the closed position, the control valve is seated in the valve seat and fluid communication between the fuel control line and the fuel return line is inhibited. When the control valve is in the open position, the control valve is lifted from the valve seat and fluid communication between the fuel control line and the fuel return line is enabled.

**[0011]** In use, a first fuel pressure differential is established across the control valve (i.e. fuel pressure upstream of the control valve is greater than fuel pressure downstream of the control valve); and a second fuel pressure differential is established across the fuel flow restriction (i.e. fuel pressure upstream of the fuel flow restriction is greater than fuel pressure downstream of the fuel flow restriction). The fuel flow restriction can be configured such that the second fuel pressure differential is greater than the first fuel pressure differential.

**[0012]** An additional fuel flow restriction could be provided upstream of the valve seat, for example in the fuel control line, to control fuel flow between the control chamber in the fuel injector and the control valve. The additional fuel flow restriction can cause a reduction in the fuel pressure upstream of the valve seat to below the fuel pressure in the control chamber. The additional fuel flow restriction upstream of the control valve can thereby reduce the first pressure differential established across the control valve. Thus, cavitation at the valve seat may be reduced. Alternatively, the fluid pathway upstream of the valve seat, i.e. between the control chamber and the control valve, can be substantially unrestricted. In this configuration, the fuel pressure upstream of the valve seat

is at least substantially equal to the fuel pressure in the control chamber.

**[0013]** A return chamber can be disposed between the valve seat and the fuel flow restriction. The return chamber can be disposed downstream of the valve seat and upstream of the fuel flow restriction. The fuel flow restriction can be adapted such that, in use, the fuel pressure in the return chamber is greater than or equal to 1000 bars, 1500 bars, 2000 bars or 2300 bars. The fuel pressure in the return chamber could be approximately 2300 bars. At least in certain embodiments, the fuel flow restriction is adapted such that, in use, the fuel pressure in the return chamber proximate to the valve seat can be maintained greater than or equal to the vapour pressure of the fuel irrespective of the operating condition of the control valve.

**[0014]** The fuel flow restriction can be disposed at or proximate to an inlet of the fuel return line. In a variant, the fuel flow restriction can be formed in the fuel return line. The fuel flow restriction can be disposed downstream of an inlet of the fuel return line.

**[0015]** The control valve assembly can comprise a valve insert. The valve insert can comprise a bore in which the control valve is movably mounted. The fuel flow restriction can be formed in the valve insert. Alternatively, the valve insert can be omitted. The control valve assembly can comprise a valve body. The fuel flow restriction can be disposed in the valve body. For example, the fuel flow restriction can be machined in the valve body.

**[0016]** The control valve assembly can comprise an upper valve guide and a lower valve guide disposed on respective sides of the valve seat. The upper and lower valve guides can be defined by the valve body. Alternatively, if the control valve assembly comprises a valve insert, the upper and lower valve guides can be defined by the valve insert.

**[0017]** According to a still further aspect of the present invention, there is provided a control valve assembly for a fuel injector, the control valve assembly comprising a control valve and a valve seat, the control valve being movable between a closed position in which fluid communication is inhibited and an open position in which fluid communication is enabled; wherein the control valve assembly comprises a fuel flow restriction disposed downstream of the valve seat for restricting the flow of fuel into or through a fuel return line.

**[0018]** According to a still further aspect of the present invention there is provided a fuel injector for injecting fuel into a combustion chamber of an internal combustion engine, the fuel injector comprising a control valve assembly as described herein. The fuel injector can comprise a control chamber for controlling a needle valve, the control chamber being connected to the fuel control line. The fluid communication between the control chamber and the fuel return line is inhibited when the control valve is in said closed position and fluid communication between the control chamber and the fuel return line is enabled

when the control valve is in said open position. A fluid pathway between the control chamber and the control valve is substantially unrestricted. In this arrangement, the fuel control line does not include a fuel flow restriction.

**[0019]** Within the scope of this application it is expressly intended that the various aspects, embodiments, examples and alternatives set out in the preceding paragraphs, in the claims and/or in the following description and drawings, and in particular the individual features thereof, may be taken independently or in any combination. Features described in connection with one embodiment are applicable to all embodiments, unless such features are incompatible.

#### BRIEF DESCRIPTION OF THE DRAWINGS

**[0020]** Embodiments of the present invention will now be described, by way of example only, with reference to the accompanying Figures, in which:

Figure 1 shows a schematic sectional view of a control valve assembly for a fuel injector according to the prior art;

Figure 2 shows a schematic representation of the pressure changes occurring in the control valve assembly shown in Figure 1;

Figure 3 shows a sectional view of a control valve assembly of a fuel injector in accordance with a first embodiment of the present invention;

Figure 4 shows a schematic representation of the pressure changes occurring in a control valve assembly of the fuel injector shown in Figure 3; and

Figure 5 shows a sectional view of a control valve assembly of a fuel injector in accordance with a second embodiment of the present invention.

#### DETAILED DESCRIPTION

**[0021]** A fuel injector 101 in accordance with a first embodiment of the present invention will now be described with reference to Figures 3 and 4.

**[0022]** The fuel injector 101 is configured for delivering fuel into a combustion chamber (not shown) of an associated internal combustion engine. The fuel injector 101 has particular application in a compression-ignition engine (i.e. a diesel engine), but the present invention could be implemented in a fuel injector for a spark-ignition engine (i.e. a gasoline engine). The terms "lower" and "upper" are herein used in relation to the orientation of the fuel injector 101 shown in the Figures, and the terms "downstream" and "upstream" are herein used in relation to the normal direction of the flow of fuel in the fuel injector 101.

**[0023]** As illustrated in Figure 3, the fuel injector 101 comprises a control valve assembly 103 for controlling actuation of a needle valve (not shown) which is movable towards and away from a needle seating (not shown) so as to control fuel injection from an injection nozzle into a

combustion chamber of an internal combustion engine. The control valve assembly 103 is provided to control fuel pressure within a control chamber 105 to control the actuation of the needle valve.

**[0024]** The control valve assembly 103 comprises a valve body 107, a valve insert 108 and a valve member 109. The valve insert 108 is mounted in a first bore 110 formed in the valve body 107. In the present embodiment, the valve insert 108 is a cylindrical valve insert. The valve member 109 is mounted in a second bore 111 formed in the valve insert 108. The valve member 109 comprises an upper valve guide 113 and a lower valve guide 114, an armature 115 fixedly mounted to the upper valve guide 113, and a valve stem 117. The valve stem 117 is arranged between the upper valve guide 113 and the lower valve guide 114. The valve stem 117 includes a control valve 119 which cooperates with a valve seat 121, as will be explained in more detail below. In the present embodiment, the control valve 119 is an annular valve. The upper valve guide 113 and the lower valve guide 114 are located on respective sides of the control valve 119. The valve member 109 has a reduced diameter between the control valve 119 and the lower valve guide 114 to form a return chamber 123. The return chamber 123 is annular and is located downstream of the control valve 119 and upstream of the lower valve guide 114. A solenoid (not shown) is adapted to actuate the armature 115 of the valve member 109 and, thereby, to control communication between a control line 125, which is in fluid communication with the control chamber 105, and a fuel return line 127, disposed downstream of the return chamber 123. The control line 125 is a high pressure line, for example fuel pressure within the control line 125 is higher than 2000 bars. The fuel return line 127 is a low pressure line, for example fuel pressure within the fuel return line 127 is lower than 50 bars.

**[0025]** The sidewall of the return chamber 123 is defined by an inner surface 129 of the valve insert 108. The valve insert 108 comprises an intermediate region 131 defining the valve seat 121 for receiving the control valve 119. When the control valve 119 is seated in the valve seat 121, the valve member 109 is in a closed position and fluid communication between the control chamber 105 and the fuel return line 127 is inhibited. The valve member 109 is in an open position when the control valve 119 is lifted from the valve seat 121. When the control valve 119 is in the open position, the control chamber 105 and the fuel return line 127 are in fluid communication. In Figure 3, the control valve 119 is shown in the open position.

**[0026]** An outer annular recess 133 is formed in an outer surface 135 of the valve insert 108 to form a pressure compensating chamber 137. The pressure compensating chamber 137 is configured to distribute the pressure of the fuel flowing from the control line 125 around the valve stem 117. The pressure compensating chamber 137 remains in fluid communication with the control line 125. An aperture 139 is formed in the valve insert

108 to maintain fluid communication between the pressure compensating chamber 137 and the control line 125. In the present embodiment, the aperture 139 is inclined relative to a longitudinal axis of the valve insert 108 to form a continuation of the control line 125. The control line 125 is defined between an outlet 149 of the control chamber 105 and the aperture 139 of the valve insert 108. The outer annular recess 133 defines upper and lower flanges 141, 143 which are a restriction fit in the first bore 110 to sealingly mount the valve insert 108 in the valve body 107. An annular channel 145 is formed around the circumference of the valve insert 108 and is adapted to communicate with the fuel return line 127.

**[0027]** The armature 115 of the valve member 109 is fixedly mounted to an upper end 147 of the upper valve guide 113 and is moveable under the influence of a magnetic field generated, in use, by an actuator comprising a solenoid (not shown). The solenoid is configured to cooperate with the armature 115 to control actuation of the valve member 109. More precisely, the solenoid is selectively energized to displace the valve member 109 to the open position in which the control valve 119 is lifted from the valve seat 121. A spring member (not shown) is provided within the actuator for biasing the valve member 109 to the closed position in which the control valve 119 is seated the valve seat 121.

**[0028]** As shown in Figure 3, a fuel flow restriction 151 is provided downstream of the valve seat 121 for restricting the flow of fuel through the fuel return line 127. In the present embodiment, the fuel flow restriction 151 is in the form of a restrictor having a length of between 0.3mm to 0.7mm (inclusive) and a diameter between 0.2mm and 0.4mm (inclusive). The fuel flow restriction 151 is provided within the valve insert 108, at an inlet 153 of the fuel return line 127. The fuel flow restriction 151 is in fluid communication with the return chamber 123 and with the fuel return line 127. The fuel flow restriction 151 is provided to maintain the fuel pressure in the return chamber 123 above the fuel pressure in the fuel return line 127 (i.e. greater than the fuel return pressure). The fuel pressure in the return chamber 123 is, for example, maintained above 2000 bars. The fuel flow restriction 151 establishes a fuel pressure differential between the return chamber 123 and the fuel return line 127. The dimensions of the fuel flow restriction 151 are chosen to ensure that the fuel pressure within the control chamber 105 remains above a vapour pressure of the fuel such that cavitation can be at least partially suppressed at the valve seat 121. Thus, when the control valve 119 is seated in the valve seat 121, the formation of vapour cavities in the fuel can be reduced or removed. At least in certain embodiments, damage to the valve seat 121 can be reduced, thereby helping to maintain performance of the control valve 119.

**[0029]** The operation of the fuel injector 101 in accordance with the present embodiment will now be described in more detail with reference to Figures 3 and 4.

**[0030]** Initially, the control valve 119 is in the closed position. The control valve 119 is seated in the valve seat

121, and communication between the control chamber 105 and the fuel return line 127 is inhibited.

**[0031]** To start the injection of fuel in the combustion chamber, the solenoid is energized and actuates the armature 115. The armature 115 and the valve member 109 are displaced towards the solenoid such that the control valve 119 is lifted from the valve seat 121, to the open position.

**[0032]** Once the control valve 119 lifts from the valve seat 121, the fuel pressure in the control chamber 105 decreases. The needle valve of the fuel injector 101 lifts from its seating to inject fuel into the cylinder. Unlike the prior art arrangement, in the present embodiment there is no fuel flow restriction formed between the control chamber 105 and the control line 125. Thus, the fuel pressure in the control line 125 is substantially equal to the fuel pressure in the control chamber 105.

**[0033]** When the control valve 119 lifts, the restriction formed by the valve seat 121 and the control valve 119 causes a first pressure differential to be established across the control valve 119, i.e. the fuel upstream of the control valve 119 is at a higher pressure than the fuel downstream of the control valve 119. As shown in Figure 4, fuel pressure upstream of the valve seat 121 is approximately 2500 bars and fuel pressure downstream of the valve seat 121 is approximately 2300 bars.

**[0034]** The fuel flow restriction 151 restricts the flow of fuel from the return chamber 123 into the fuel return line 127. The fuel pressure in the return chamber 123 is therefore higher than the fuel return pressure in the fuel return line 127. A second pressure differential is established across the fuel flow restriction 151. As shown in Figure 4, the fuel pressure in the fuel return line 127, or fuel return pressure, downstream of the fuel flow restriction 151, is at approximately 5 bars.

**[0035]** Once fuel has flowed through the fuel flow restriction 151, fuel exits the fuel injector 101 through the fuel return line 127. The fuel then flows out of the fuel injector 1 via an outlet of the fuel return line 127, where it is subsequently directed to a reservoir for re-use in a subsequent injection cycle.

**[0036]** In order to terminate injection, the solenoid is de-energised, and the spring member biases the armature 115 away from the solenoid and the control valve 119 towards the valve seat 121, thereby displacing the valve member 109 to the closed position. Such movement of the control valve 119 prevents further fuel from flowing from the control chamber 105 to the fuel return line 127, and the continued supply of fuel from the high pressure fuel supply line to the control chamber 105 results in an increase of the fuel pressure within the control chamber 105. Therefore, the fuel pressure applied to the upper end of the needle valve increases, and a point will be reached beyond which the action of the fuel pressure within the control chamber 105 in combination with the action of the spring member is sufficient to cause the needle valve to move towards engagement with its seating and terminate injection.

**[0037]** Upon closure of the control valve 119, the inertia of the fuel creates a low pressure region at or proximate to the valve seat 121. However, the fuel flow restriction 151 maintains the fuel pressure in the return chamber 123 at a higher pressure than the fuel pressure in the fuel return line 127 (i.e. the fuel in the return chamber 123 is at a higher pressure than the fuel return pressure). The increased pressure in the return chamber 123 helps to reduce or inhibit cavitation at the valve seat 121. In the present embodiment, the fuel flow restriction 151 is configured such that the fuel pressure in the return chamber 123 is sufficiently high that the fuel pressure remains at or above the vapour pressure of the fuel even in the low-pressure region established proximate to the valve seat 121 due to the inertia of the fuel when the control valve 119 closes. By reducing cavitation in the fuel, damage to the valve seat 121 may be reduced and the performance of the control valve assembly 103 can be preserved.

**[0038]** It will be appreciated that various changes and modifications can be made to the fuel injector described herein without departing from the scope of the present invention, as set out in the appended claims.

**[0039]** For example, the fuel injector 101 has been described having the fuel flow restriction 151 formed in the valve insert 108 of the fuel injector 101. A fuel injector 201 according to a second embodiment of the present invention is shown in Figure 5. The second embodiment corresponds closely to the first embodiment and like reference numerals have been used for like components. In this embodiment, a fuel flow restriction 251 is formed in the fuel return line 127. In this arrangement, the fuel flow restriction 251 is disposed downstream of the inlet to the fuel return line 127. The operation of the modified fuel injector 201 is unchanged from the embodiment 101 described above. In particular, the fuel flow restriction 251 is adapted to restrict the flow of fuel through the fuel return line downstream of the valve seat 121.

## Claims

1. A control valve assembly (103) for controlling fuel pressure within a control chamber (105) of a fuel injector (101, 201), the control valve assembly (103) comprising:

a control valve (119) and a valve seat (121);  
 a fuel control line (125) for connection to the control chamber (105); and  
 a fuel return line (127);  
 the control valve (119) being movable between a closed position for inhibiting fluid communication between the fuel control line (125) and the fuel return line (127) and an open position for enabling fluid communication between the fuel control line (125) and the fuel return line (127);  
 wherein a fuel flow restriction (151, 251) is pro-

vided downstream of the valve seat (121) for maintaining the fuel pressure in a region between the valve seat (121) and the fuel flow restriction (151, 251) above a return pressure of fuel in the fuel return line (127).

2. A control valve assembly (103) as claimed in claim 1, wherein the fuel flow restriction (151, 251) is configured such that, in use, the fuel pressure proximate to the valve seat (121) remains at or above a vapour pressure of the fuel.
3. A control valve assembly (103) as claimed in claim 1 or claim 2, wherein a fluid pathway upstream of the valve seat (121) is substantially unrestricted.
4. A control valve assembly (103) as claimed in any one of the preceding claims, wherein the control valve assembly (103) comprises an upper valve guide (113) and a lower valve guide (114) disposed on respective sides of the valve seat (121).
5. A control valve assembly (103) as claimed in any one of claims 1 to 4, wherein a return chamber (123) is disposed between the valve seat (121) and the fuel flow restriction (151, 251).
6. A control valve assembly (103) as claimed in claim 5, wherein the fuel flow restriction (151, 251) is adapted such that, in use, the fuel pressure in the return chamber (123) is maintained greater than or equal to the vapour pressure of the fuel.
7. A control valve assembly (103) as claimed in claim 5 or claim 6, wherein the fuel flow restriction (151, 251) is adapted such that, in use, the fuel pressure in the return chamber (123) is greater than 2000 bars.
8. A control valve assembly (103) as claimed in any one of the preceding claims, wherein the fuel flow restriction (151) is configured to restrict the flow of fuel into or through the fuel return line (127).
9. A control valve assembly (103) as claimed in any one of the preceding claims, wherein the fuel flow restriction (151) is disposed at, or proximate to an inlet (153) of the fuel return line (127).
10. A control valve assembly (103) as claimed in any one of the preceding claims, wherein the control valve assembly (103) comprises a valve insert (108), and the fuel flow restriction (151) is disposed in the valve insert (108).
11. A control valve assembly (103) as claimed in any one of claims 1 to 8, wherein the fuel flow restriction (251) is disposed downstream of an inlet (153) of the fuel return line (127).

12. A fuel injector (101, 201) for injecting fuel into a combustion chamber of an internal combustion engine, the fuel injector (101, 201) comprising:

a control valve assembly (103) as claimed in any one of the preceding claims; and  
a control chamber (105) for controlling a needle valve, the control chamber (105) being connected to the fuel control line (125);  
wherein fluid communication between the control chamber (105) and the fuel return line (127) is inhibited when the control valve (119) is in said closed position and fluid communication between the control chamber (105) and the fuel return line (127) is enabled when the control valve (119) is in said open position.

13. A fuel injector (101, 201) as claimed in claim 12, wherein a fluid pathway between the control chamber (105) and the control valve (119) is substantially unrestricted.

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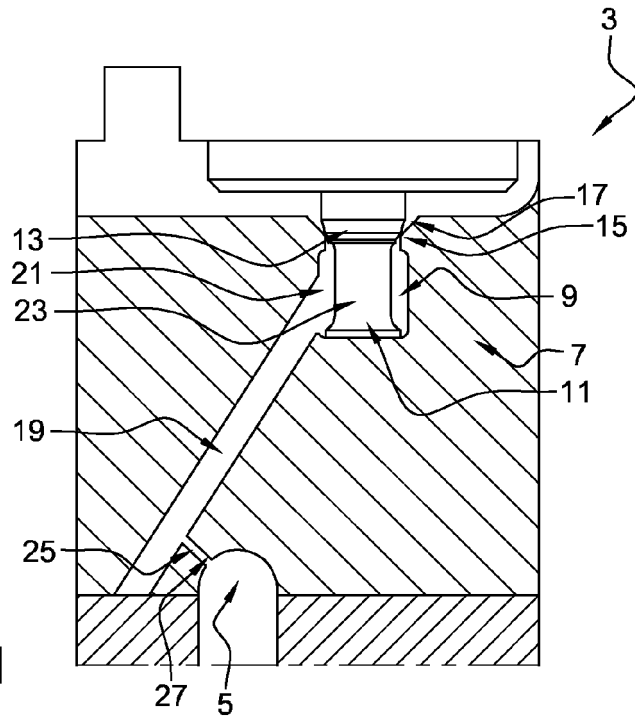
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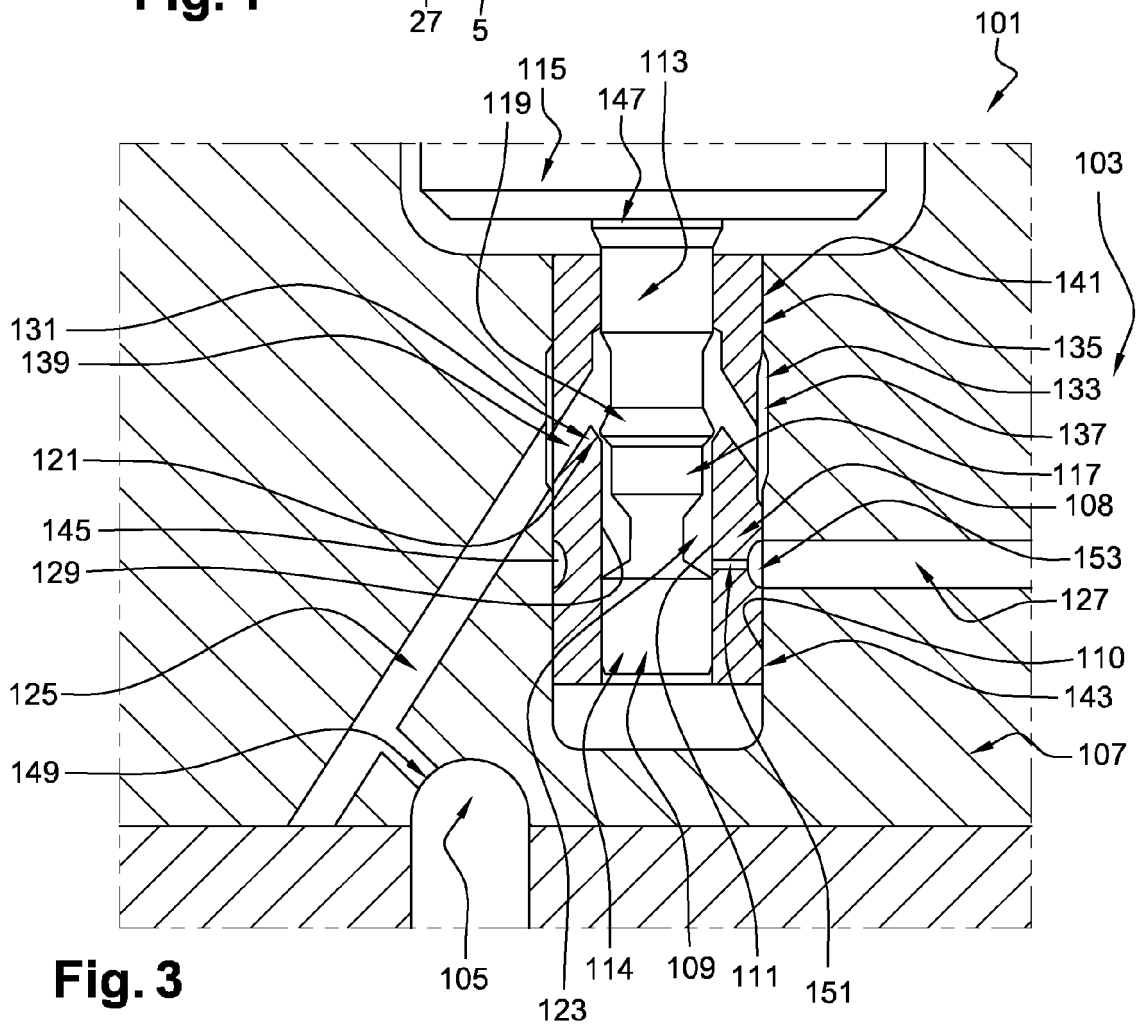
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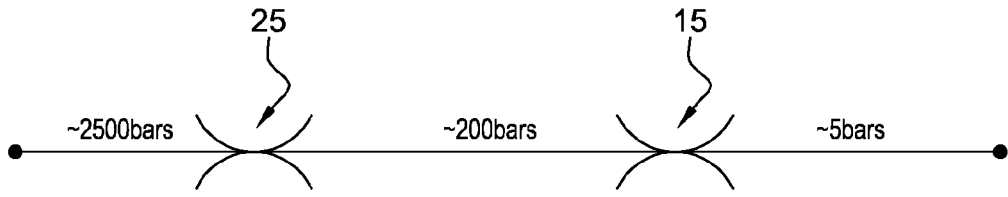
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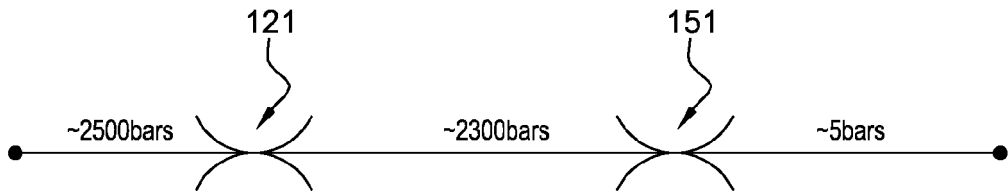
**Fig. 1**



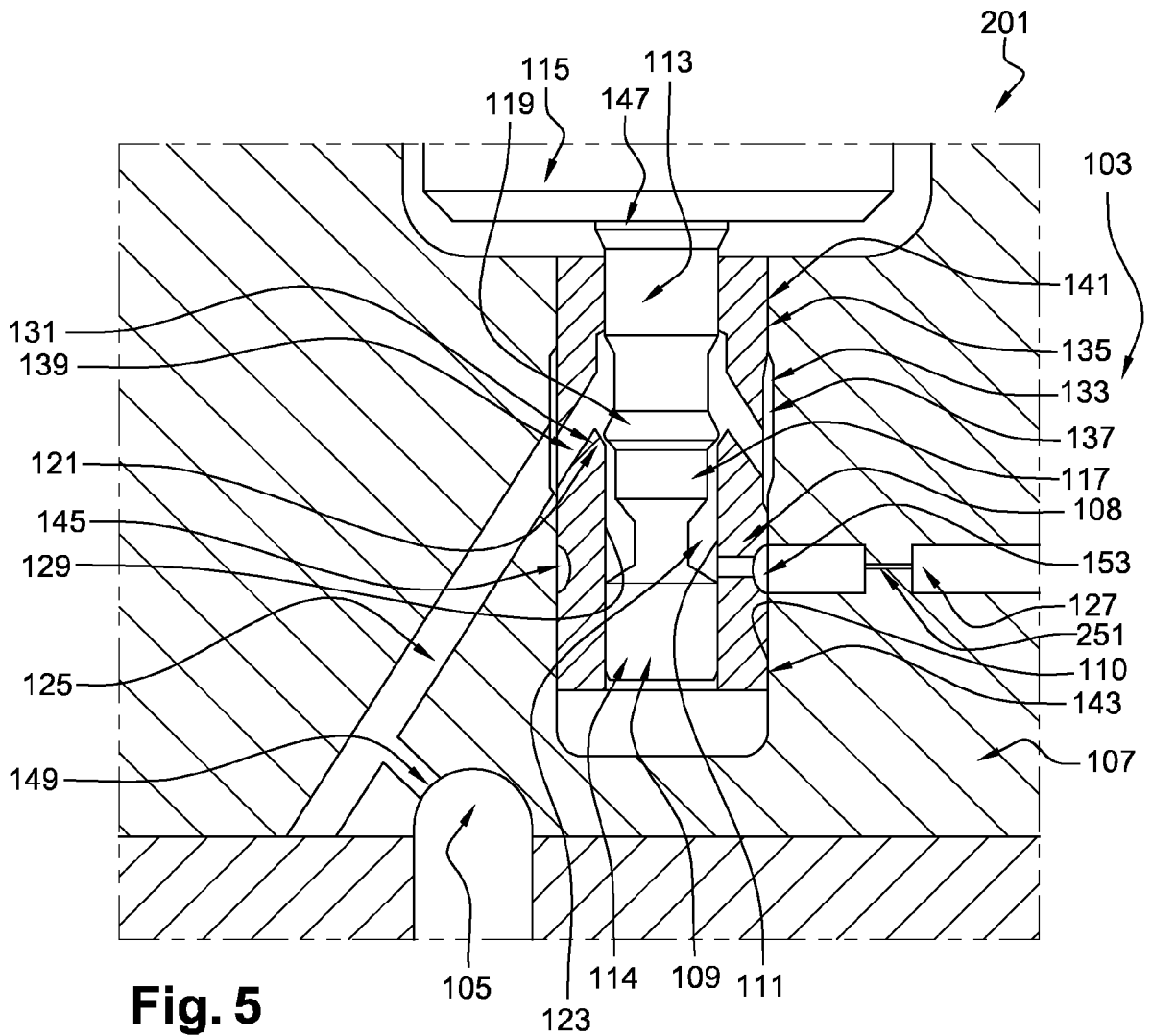
**Fig. 3**



**Fig. 2**



**Fig. 4**



**Fig. 5**



EUROPEAN SEARCH REPORT

Application Number  
EP 15 17 1107

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DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 2013/153686 A1 (KEELER NATHAN PETER [GB]) 20 June 2013 (2013-06-20)  * paragraph [0067] - paragraph [0069] * * abstract; figures 3,4 * * paragraph [0059] *  -----	1,2,5,6, 8,9,11, 12	INV. F02M47/02 F02M55/00
X	US 5 979 790 A (GUERICH GUNTER [DE] ET AL) 9 November 1999 (1999-11-09) * abstract; figures 1,2 * * claims 1,2,3,4 * * column 2, line 17 - line 26 * * column 2, line 17 - line 26 * * column 3, line 51 * * column 3, line 51 - line 64 * * column 4, line 37 - line 64 * * column 3, line 65 - column 4, line 3 *	1,3-5, 8-13	
X	EP 1 614 893 A1 (DENSO CORP [JP]) 11 January 2006 (2006-01-11)  * abstract; figures 1,2 * * paragraph [0004] * * claims 1,3,9 * * paragraph [0033] * * paragraph [0032] *  -----	1,3,5, 8-10,12, 13	TECHNICAL FIELDS SEARCHED (IPC)  F02M
X	US 5 975 428 A (POTSCHIN ROGER [DE] ET AL) 2 November 1999 (1999-11-02) * column 6, line 10 - line 28 * * abstract; figures 1,2,3 * * column 4, line 49 - column 5, line 4 * * claims 1,11 *  -----  -/--	1,3,5,8, 9,11-13	
The present search report has been drawn up for all claims			
Place of search <b>The Hague</b>		Date of completion of the search <b>22 October 2015</b>	Examiner <b>Barunovic, Robert</b>
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons ..... & : member of the same patent family, corresponding document	

EPO FORM 1503 03.02 (F04C01)



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