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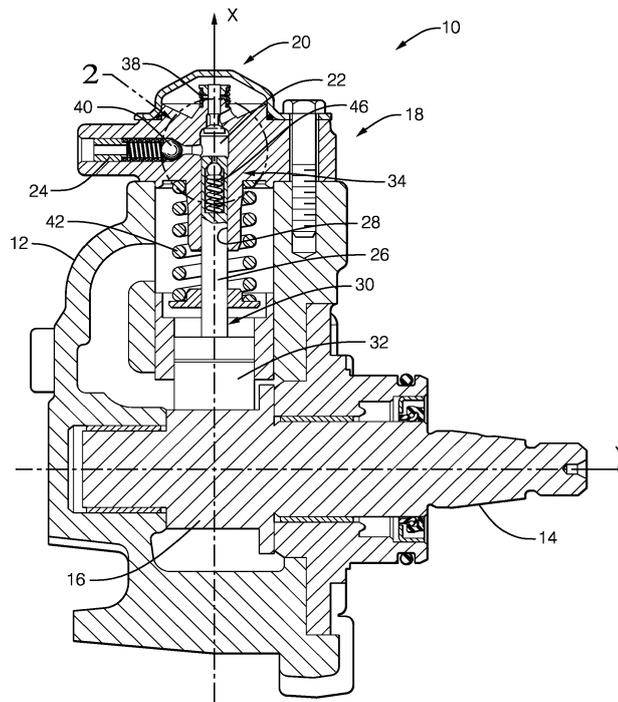
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(54) **HIGH PRESSURE FUEL PUMP**

(57) High pressure fuel pump (10) having a pumping head (18) wherein a compression chamber (22) is defined between the blind end of a bore (28) and the head end (34) of a plunger slidably adjusted in said bore (28).

The plunger (26) is provided with an inner chamber (46) in fluid communication with the compression chamber (22) via an opening orifice arranged in the head end (34) of the plunger.



**FIG. 1**

**Description**

## TECHNICAL FIELD

**[0001]** The present invention relates to a cam actuated high pressure pump and more particularly to a plunger arrangement.

## BACKGROUND OF THE INVENTION

**[0002]** A diesel internal combustion engine (ICE) comprises a fuel injection equipment wherein fuel sucked from a low pressure tank is pressurized at 2000 bars or higher in a cam actuated high pressure pump, prior to be delivered to a high pressure reservoir, or common rail, to which are connected a plurality of fuel injectors. A command unit controls the equipment as a function of the demand of fuel from the ICE.

**[0003]** In the high pressure pump, fuel is pressurized in a compression chamber defined between the head end of a plunger and the blind end of a bore. The plunger reciprocates in the bore therein performing a pumping cycle during which the inner volume of the compression chamber is varied. As said volume reduces instead of being pressurized, part of the fuel leaks between the plunger and the bore, through a clearance that enlarges as the pressure in the chamber rises.

**[0004]** To limit or reduce said leaks to the minimum acceptable and still enabling plunger to bore lubrication several solutions have been tested such as plungers provided with a deep recess opening on their head end. In operation the recess is filled with fuel and, when the pressure rises the peripheral wall of the recess slightly expands and closes, at least partially, the clearance.

**[0005]** Unfortunately, the recess augments the quantity of pressurized fuel above the necessary engine demand then, the pressure of said undelivered over-quantity alternatively rises and drops, this representing important energy losses.

## SUMMARY OF THE INVENTION

**[0006]** Accordingly, it is an object of the present invention to resolve the above mentioned problems in providing a high pressure fuel pump having a pumping head wherein a compression chamber is defined between the blind end of a bore and the head end of a plunger slidably adjusted in said bore and adapted to perform therein a pumping cycle varying the volume of said compression chamber.

**[0007]** The pump is further provided with inlet and outlet valve assemblies for controlling fuel flowing in and out of said compression chamber.

**[0008]** Advantageously, the plunger is provided with an inner chamber arranged in the head end of the plunger that is in the vicinity of the compression chamber, said inner chamber being in fluid communication with the compression chamber via an opening orifice arranged in the

head end of the plunger.

**[0009]** Also, said plunger inner chamber is defined by a peripheral wall adapted to expand when the plunger inner chamber is under pressure.

**[0010]** The high pressure fuel pump is further provided with a check valve assembly arranged to control said fluid communication.

**[0011]** Also, said check valve assembly is normally in a closed state of the opening orifice and is arranged to open the fluid communication only when the pressure in the compression chamber exceeds the pressure in the plunger inner chamber.

**[0012]** Said check valve assembly comprises a spring member biasing a valve member against a seating face surrounding said opening.

**[0013]** Also, the valve member and the spring member are both arranged inside the plunger inner chamber.

**[0014]** More precisely, the plunger is provided with a recess arranged on its head end, said recess defining the inner chamber, the peripheral wall axially extending toward a top circular extremity. Said peripheral wall receiving a plugging cap adjusted and fixed to said top circular extremity. The plugging cap is provided with a central opening defining the fluid communication between the compression chamber and the plunger inner chamber and, wherein the valve member and the spring member are arranged in the inner chamber prior to the fixation of the plugging cap on top circular extremity.

**[0015]** Also, the plugging cap is screwed within the peripheral wall of the recess.

**[0016]** The plunger comprises a main part onto which is adjusted and fixed a tubular head member defining the inner chamber, and the check valve assembly being arranged in place prior to fixing the head member.

**[0017]** Also, said head member has a cylindrical peripheral wall extending from a lower end, adapted to be complementary adjusted and fixed onto the main part of the plunger, to an upper end provided with a radial shoulder face provided with the opening orifice.

**[0018]** Furthermore, the check valve assembly is arranged in the plunger inner chamber by insertion through the opening orifice, the valve member being adjusted in sliding fit in the orifice of the fluid communication and, having at least one retractable arm member adapted to retract when inserted through said orifice and, to expand once inside the inner chamber, said retractable arm member preventing exit of the check valve assembly through the opening orifice.

**[0019]** Said retractable arm member is a flexible arm extending from a first extremity, fixed to said closing member, to a distant free extremity, the arm extending substantially along the lateral face of the closing member while distancing slightly from it, the first extremity being inserted first through the opening orifice when the check valve assembly is inserted in the plunger inner chamber.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0020]** The present invention is now described by way of example with reference to the accompanying drawings in which:

Figure 1 is a general section of a high pressure pump as per the invention.

Figure 2 is magnified portion of the compression chamber of the pump of figure 1 as per a first embodiment.

Figure 3 is similar to figure 2 representing a second embodiment of the invention.

Figures 4 and 5 represent a third alternative of the invention.

## DESCRIPTION OF THE PREFERRED EMBODIMENTS

**[0021]** In reference to figure 1 is described a high pressure fuel pump 10 adapted to be arranged in a diesel fuel injection equipment not represented.

**[0022]** The pump 10 comprises a body 12 wherein a camshaft 14 having a cam 16 is arranged to rotate between two bearings about a cam axis Y. On the body 12 is fixedly arranged a pumping head 18 wherein fuel entering via an inlet 20 in a compression chamber 22 exits after being pressurized via an outlet 24.

**[0023]** In use, fuel compression occurs during a pumping cycle wherein a plunger 26 reciprocally slides between a bottom dead center (BDC) position and a top dead center (TDC) position in a bore 28 of the pumping head 18. The plunger 26 extends along a pumping axis X, perpendicular to the cam axis Y, from a foot end 30, protruding outward the pumping head 18 and cooperating with the cam 16 via a cam follower 32, to a head end 34 that is in the bore and which extreme transverse face 36, or top face 36 of the plunger, partly defines the compression chamber 22.

**[0024]** The inlet 20 is controlled by an inlet valve member 38 arranged at the end of the bore 28 and, the outlet 24 radially arranged relative to the compression chamber 22 is controlled by an outlet valve member 40, which in the representation of figure 1 is a check valve with a ball biased by a coil spring in a closed position against a conical seating face.

**[0025]** The compression chamber 22 is fully defined by the space comprised between said extreme transverse face 36 of the plunger and the end of the bore 28, being a cylindrical end of the bore and the under face of the inlet valve member 38.

**[0026]** Finally a spring pump 42 compressed between the pumping head 18 and the cam follower 32 permanently bias said follower 32 against the cam 16.

**[0027]** In use, when the camshaft 14 rotates, the cam 16 imparts to the plunger 26 said reciprocating movement performing said pumping cycle during which the inner volume of the compression chamber 22 is varied.

**[0028]** The region of the compression chamber 22 is

now detailed in reference to figure 2, where is shown that the outlet 24 radially opens in the final portion 44 of the bore and where the head end 34 of the plunger extends in said enlarged portion 44 when in TDC. In order to avoid closing the outlet 24 by the plunger 26, said final portion 44 of the plunger is slightly enlarged in section.

**[0029]** Also, the plunger 26 is provided on its head end 34 with an inner plunger chamber 46 in fluid communication FC with the compression chamber 22 via a top orifice 48 opening in the transverse top face 36. Said fluid communication FC is controlled by a check valve 50 arranged inside the chamber 46.

**[0030]** A first embodiment of the invention is presented on figure 2 where a deep recess provided at the head end of the plunger 26 defines a thin peripheral wall 52 threaded 54 in the region opening in the transverse top face 36. The deepness D of the recess is such that, when in TDC, the peripheral wall 52 extends in the enlarged portion 44 of the bore and also in the lower main part of the bore that is not enlarged. Therefore, the outer face of the peripheral wall 52 is slidably guided against said main bore face. A male threaded plugging cap 56 is complementary screwed in the threaded area of the peripheral wall of the plunger, said cap 56 defining the top transverse face 34 of the plunger and, at the opposite, a top face 58 of the inner chamber 46. Said top face 58 is centrally provided with a conical face so as to form a valve seating face 59, the orifice 48, creating the fluid communication FC, being provided from the tip of said conical or sloped seating face 59 to the opposite top transverse face 36. The position of the cap 56 is permanently secured via a weld seam 60 or any other known fixation means.

**[0031]** Inside the chamber 46 the check valve 50 is arranged prior to screwing the cap 56. The check valve 50 comprises a valve member 62, which in this first embodiment is a ball, permanently biased by a valve spring 64 against the seating face 59. As will be explained, the valve spring 64 has a relatively low stiffness and is just adapted to maintain the ball 62 in biasing contact against the seating face 58.

**[0032]** During the very first pumping cycle, when the plunger is at BDC, non-pressurized fuel has filled the bore, the pressure inside the inner chamber 44 is low and the orifice 48 is closed by the check valve 50.

**[0033]** As the camshaft rotates, the plunger initiates a move from BDC toward TDC, the pressure in the compression chamber rises and the check valve 50 opens letting fuel to enter the inner chamber 46, the pressure rising in said chamber 46.

**[0034]** As the plunger approaches TDC, the pressure in the compression chamber and inside the inner chamber 46 are substantially equal.

**[0035]** After delivering the pressurized fuel through the outlet 24 and emptying the compression chamber, the pressure in the compression chamber drops and the check valve 50 closes the fluid communication FC, the pressure in the inner chamber 46 remaining very high.

**[0036]** During the subsequent pumping cycles, the pressure in the compression chamber varies upon the demand of the engine while the pressure in the inner chamber 46 remains at said very high level. In fact, the fluid communication FC only opens when the pressure in the compression chamber gets higher than the pressure in the inner chamber 46 and consequently, said pressure in the inner chamber 46 permanently remains very high. The stiffness of the spring 64 is chosen to be low in order to enable the fluid communication FC to open upon superior pressure in the compression chamber 22. When the pressure in the inner chamber 46 is the highest, the spring 62 positions the ball 62 against the seating face 58 while said high inner pressure generates on the ball a biasing force ensuring closing of the fluid communication FC.

**[0037]** Under the influence of said high pressure inside the inner chamber 46, the peripheral wall 52 radially expands and reduces the functional gap between the main non-enlarged portion of the bore, and the plunger and, in doing this the fuel leakages around the plunger are reduced.

**[0038]** A second embodiment of the invention is now described in reference to figure 3 and by ways of differences to the first embodiment. The main difference is that in the first embodiment the peripheral wall of the inner chamber is integral to the plunger while, in the second embodiment said wall is integral to an elongated head member 66 screwed at the end of the plunger.

**[0039]** More in details, as shown on figure 3, the plunger 26 is shorter than previously and its very end portion has a reduced diameter which is threaded 54 for complementary arrangement of the elongated up-side-down cup-like head member 66 forming the complete head end 34 of the plunger and defining the inner chamber 46. Said elongated head member 66 has a peripheral tubular wall 68 externally adjusted to be in sliding fit against the main non-enlarged part of the bore. The inner chamber 46 is defined inside said peripheral wall 68 which extends, from a bottom end internally threaded for complementary arrangement on the top of the plunger, to an opposite transverse wall forming the transverse top face 36 and centrally pierced with the top orifice 48 which inner opening is surrounded by the seating face 59. The final positioning of the elongated head member 66 on the plunger is secured via a weld seam 60 or via any other known fixing means.

**[0040]** Here again the check-valve 50, which is identical to the check valve of the first embodiment, is arranged inside the inner chamber 46 before screwing the head member 66 in place.

**[0041]** The operation of this second embodiment is identical to the previous description.

**[0042]** A third embodiment is now described in reference to figures 4 and 5 where the inner chamber is integrally formed in the head 34 of the plunger and, another check valve 70 is arranged in place by insertion through the top orifice 48. For easiness of manufacturing, the

inner chamber 48 can be provided either fully integral to the plunger as represented on figure 4, or can alternatively be in the form of either one of the previous embodiments, with a plugging cap or an elongated cap. The main difference with the first or second embodiments is said another check-valve 70 is designed to be inserted through the top orifice 48. The valve member 72 of said another check valve comprises a cylindrical portion that is adjusted in a sliding fit with the orifice 48. It is further provided with side arms 74, one, two or more, that upwardly and radially extend from a first end attached to said cylindrical portion to a distant second end. The side arms can be articulated at their first end or can be designed flexible. The spring 64 of the check valve is attached to the valve member 72 and, as represented, a foot member 76 can be attached to the lower end of the spring. When arranged in place, the foot member 76 is engaged first, the spring follows and, when the valve member 72 is engaged the first end of the arms 74 engage first in the top orifice 48 and the arms 74 retracts and align in order to enable full engagement of the valve member 72. Once fully engaged and the arms 74 totally inside the inner chamber 46, the arms 74 radially expand and prevent any exit of the check valve. The spring forces the valve member 72 toward the outside while the arms 74 forbid such move.

**[0043]** The operation is globally the same as previously described to the difference that the sliding fit of the valve member 72 into the orifice 48 does not perfectly seal the orifice as well as in the previous cases. So, in operation, when the pressure in the compression chamber 22 drops below the pressure in the inner chamber 46, pressurized fuel captured in the inner chamber may partially leak between the valve member 72 and the top orifice 48 and reach the compression chamber.

#### LIST OF REFERENCES

##### **[0044]**

|     |                             |
|-----|-----------------------------|
| X   | pumping axis                |
| Y   | cam axis                    |
| BDC | bottom dead center position |
| TDC | top dead center position    |
| FC  | fluid communication         |
| D   | deepness of the recess      |
| 10  | pump                        |
| 12  | pump body                   |
| 14  | camshaft                    |
| 16  | cam                         |
| 18  | pumping head                |
| 20  | inlet                       |
| 22  | compression chamber         |
| 24  | outlet                      |
| 26  | plunger                     |
| 28  | bore                        |
| 30  | foot end of the plunger     |

32 cam follower  
 34 head end of the plunger  
 36 transverse face - top face  
 38 inlet valve member  
 40 outlet valve member  
 42 spring pump  
 44 final enlarged portion of the bore  
 46 inner chamber of the plunger  
 48 top orifice  
 50 check valve  
 52 peripheral wall  
 54 thread  
 56 plugging cap  
 58 top face of the inner chamber  
 59 seating face  
 60 weld seam  
 62 valve member - ball  
 64 spring  
 66 elongated tubular head member  
 68 peripheral wall of the elongated cap  
 70 another check valve  
 72 valve member  
 74 side arms  
 76 foot member

#### Claims

1. High pressure fuel pump (10) having a pumping head (18) wherein a compression chamber (22) is defined between the blind end of a bore (28) and the head end (34) of a plunger slidably adjusted in said bore (28) and adapted to perform therein a pumping cycle varying the volume of said compression chamber (22),  
 the pump (10) being further provided with inlet (20) and outlet (24) valve assemblies for controlling fuel flowing in and out of said compression chamber (22),  
**characterized in that**  
 the plunger (26) is provided with an inner chamber (46) arranged in the head end (34) of the plunger that is in the vicinity of the compression chamber (22), said inner chamber (46) being in fluid communication (FC) with the compression chamber (22) via an opening orifice (48) arranged in the head end (34) of the plunger.
2. High pressure fuel pump (10) as claimed in the preceding claim wherein said plunger inner chamber (46) is defined by a peripheral wall (52) adapted to expand when the plunger inner chamber (46) is under pressure.
3. High pressure fuel pump (10) as claimed in any one of the preceding claims further provided with a check valve assembly (50) arranged to control said fluid communication (FC).
4. High pressure fuel pump (10) as claimed in claim 3 wherein said check valve assembly (50) is normally in a closed state of the opening orifice (48) and is arranged to open the fluid communication (FC) only when the pressure in the compression chamber (22) exceeds the pressure in the plunger inner chamber (46).
5. High pressure fuel pump (10) as claimed in any one of the claims 3 or 4 wherein said check valve assembly (50) comprises a spring member (64) biasing a valve member (62) against a seating face (59) surrounding said opening.
6. High pressure fuel pump (10) as claimed in claim 5 wherein the valve member (62) and the spring member (64) are both arranged inside the plunger inner chamber (46).
7. High pressure fuel pump (10) as claimed in any one of the preceding claims wherein the plunger (26) is provided with a recess arranged on its head end (34), said recess defining the inner chamber (46), the peripheral wall (52) axially extending toward a top circular extremity, said peripheral wall (52) receiving a plugging cap (56) adjusted and fixed to said top circular extremity, the plugging cap (56) being provided with a central opening defining the fluid communication (FC) between the compression chamber (22) and the plunger inner chamber (46), and wherein the valve member (62) and the spring member (64) are arranged in the inner chamber (46) prior to the fixation of the plugging cap (56) on top circular extremity.
8. High pressure fuel pump (10) as claimed in claim 7 wherein the plugging cap (56) is screwed within the peripheral wall (52) of the recess.
9. High pressure fuel pump (10) as claimed in any one of the claims 1 to 6 wherein the plunger (26) comprises a main part onto which is adjusted and fixed a tubular head member (66) defining the inner chamber (46), the check valve assembly (50) being arranged in place prior to fixing the head member (34).
10. High pressure fuel pump (10) as claimed in claim 9 wherein said head member (34) has a cylindrical peripheral wall (52) extending from a lower end, adapted to be complementary adjusted and fixed onto the main part of the plunger (26), to an upper end provided with a radial shoulder face provided with the opening orifice.
11. High pressure fuel pump (10) as claimed in any one of the claims 1 to 4 wherein the check valve assembly (70) is arranged in the plunger inner chamber (46) by insertion through the opening orifice (48), the valve member (72) being adjusted in sliding fit in the

orifice (48) of the fluid communication (FC) and, having at least one retractable arm member (74) adapted to retract when inserted through said orifice (48) and, to expand once inside the inner chamber (46), said retractable arm member (74) preventing exit of the check valve assembly (70) through the opening orifice. 5

12. High pressure fuel pump (10) as claimed in claim 11 wherein said retractable arm member (74) is a flexible arm extending from a first extremity, fixed to said closing member, to a distant free extremity, the arm extending substantially along the lateral face of the closing member while distancing slightly from it, the first extremity being inserted first through the opening orifice when the check valve assembly (50) is inserted in the plunger inner chamber (46). 10 15

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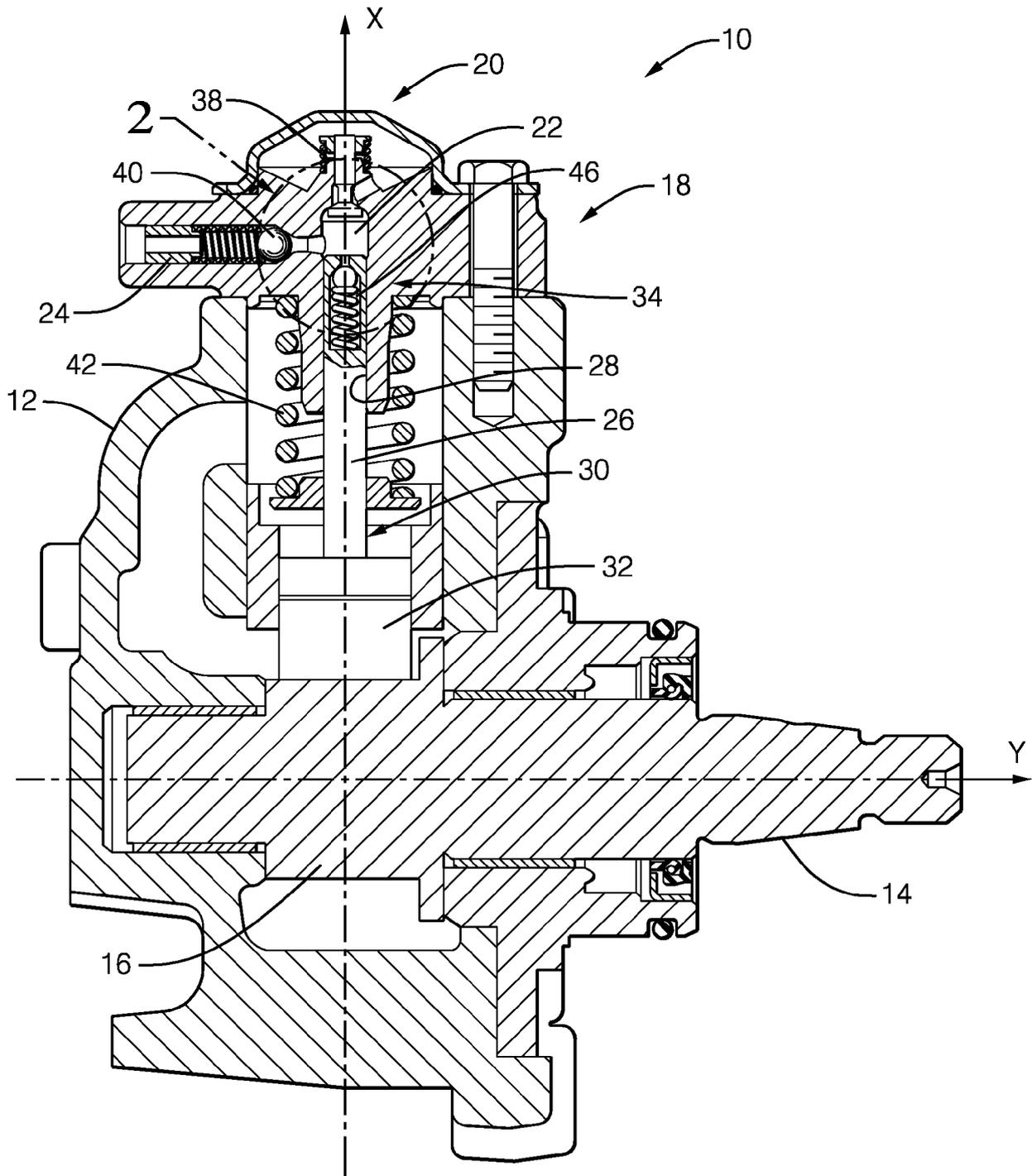


FIG. 1

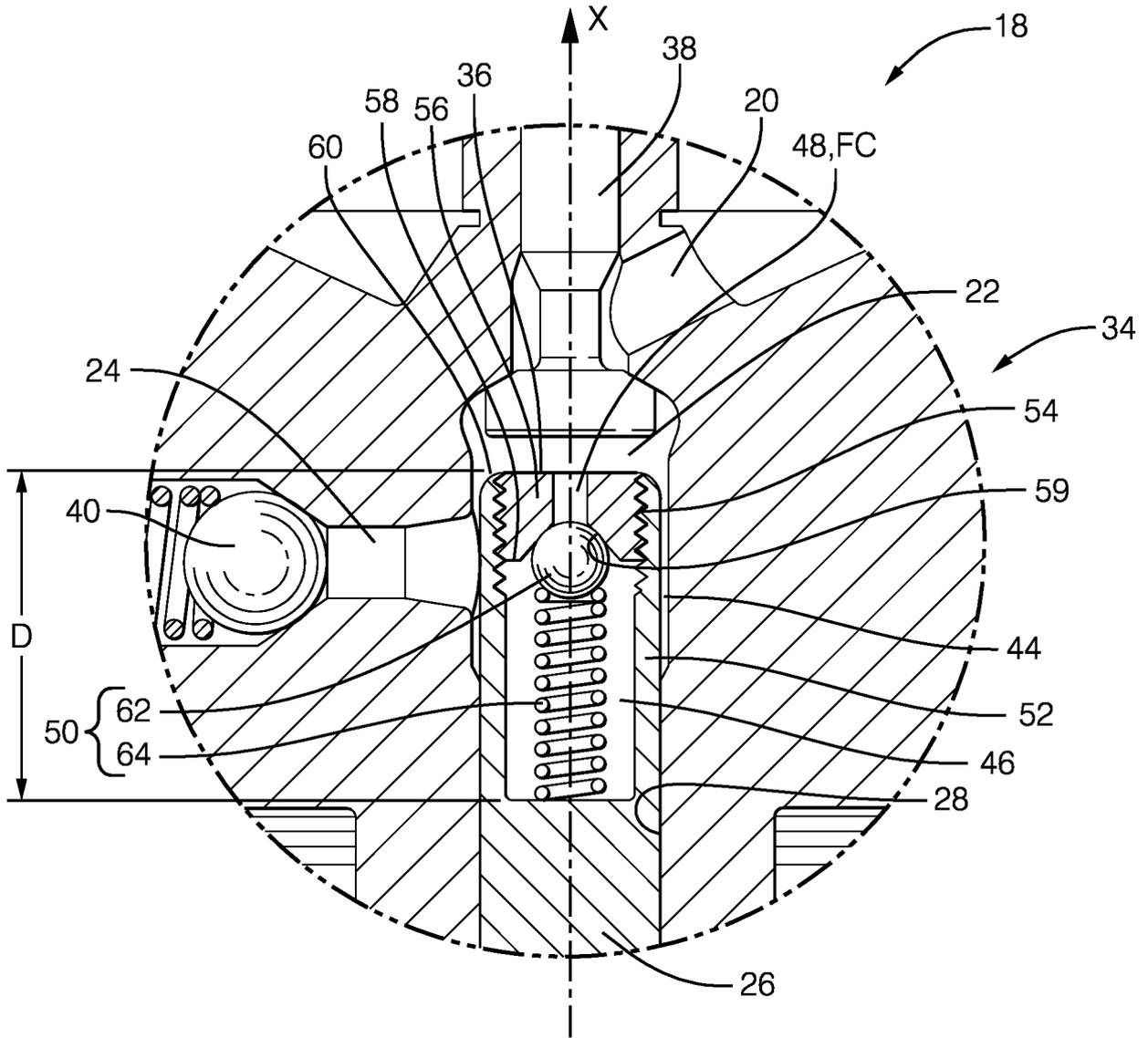


FIG. 2

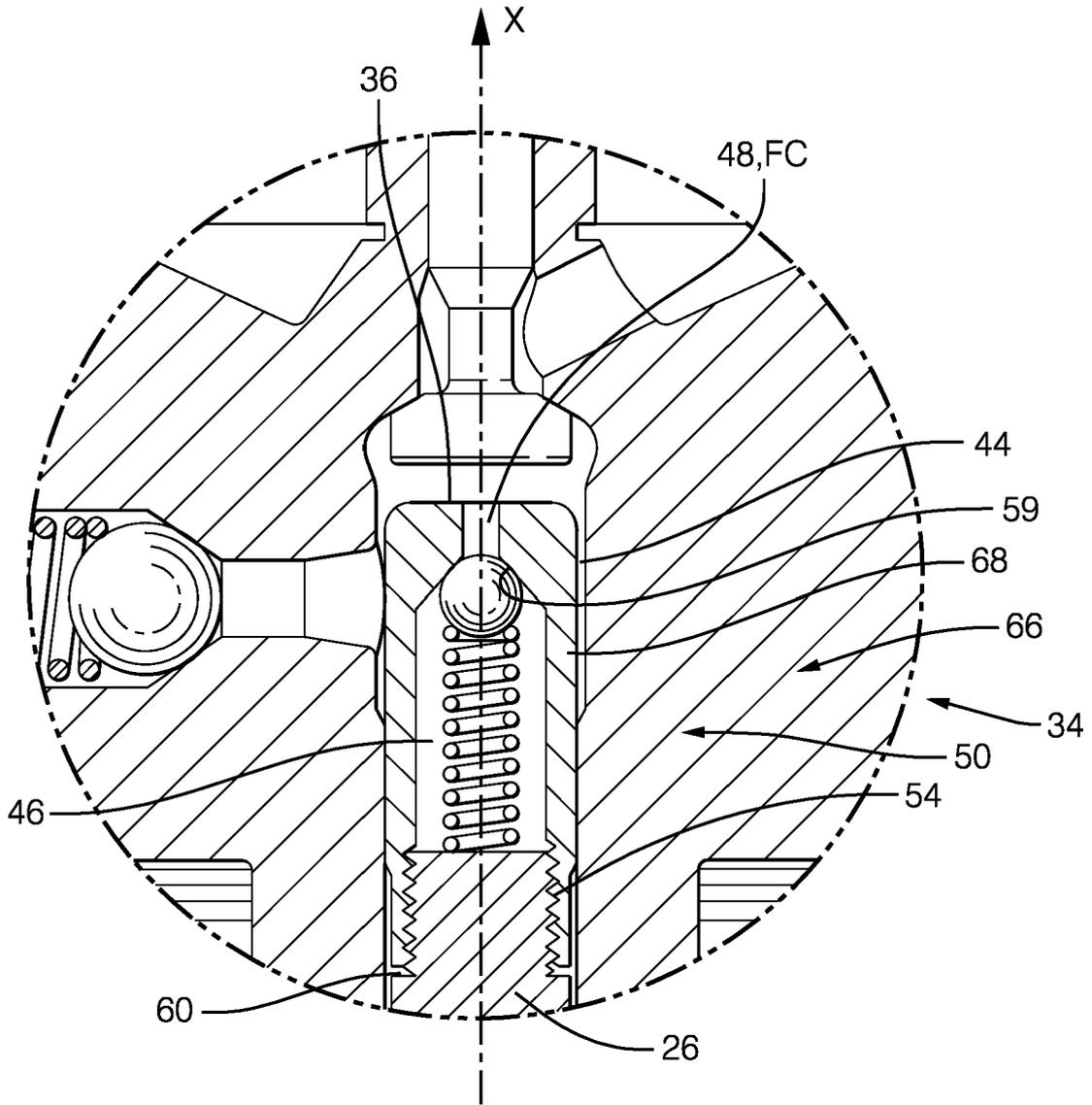


FIG. 3

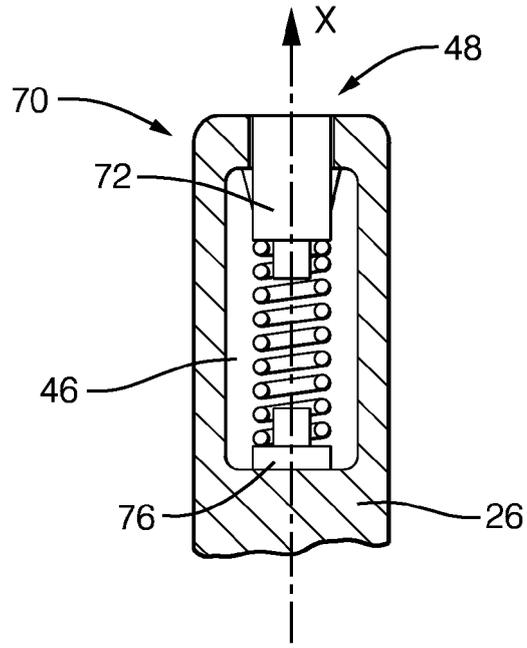


FIG. 4

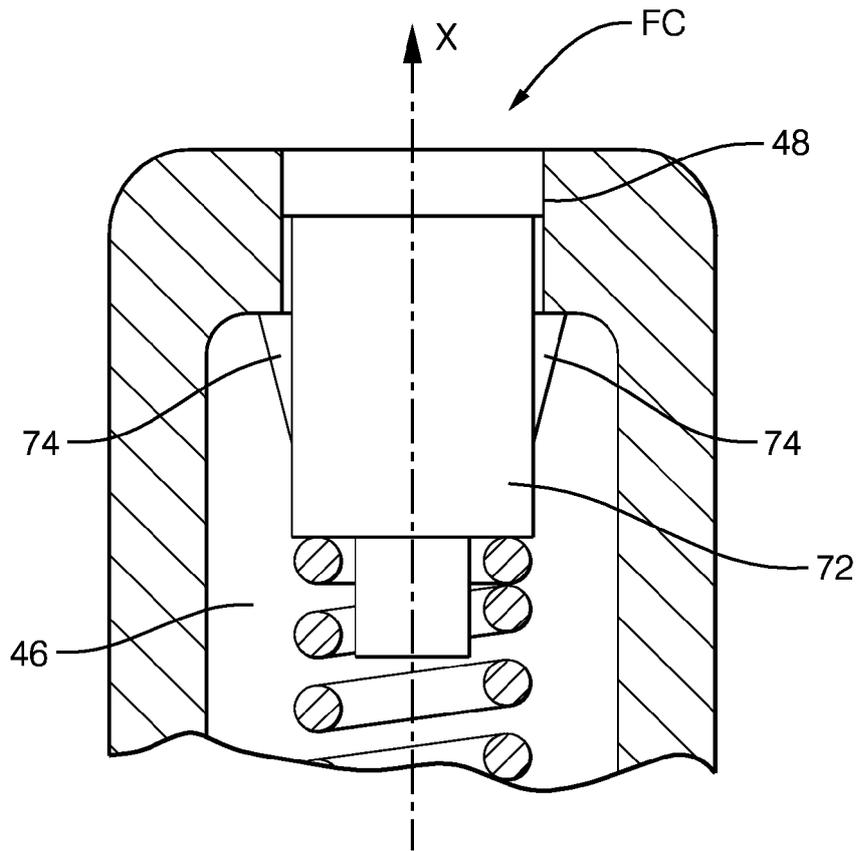


FIG. 5



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Application Number  
EP 17 16 7344

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| The present search report has been drawn up for all claims  |   |  |   |
| Place of search<br><b>The Hague</b>   |   | Date of completion of the search<br><b>27 June 2017</b>  | Examiner<br><b>Morales Gonzalez, M</b>      |
| CATEGORY OF CITED DOCUMENTS   |   | T : theory or principle underlying the invention<br>E : earlier patent document, but published on, or after the filing date<br>D : document cited in the application<br>L : document cited for other reasons |   |
| X : particularly relevant if taken alone<br>Y : particularly relevant if combined with another document of the same category<br>A : technological background<br>O : non-written disclosure<br>P : intermediate document |   | & : member of the same patent family, corresponding document   |   |

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ANNEX TO THE EUROPEAN SEARCH REPORT  
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5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.  
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