



(11) **EP 3 990 772 B1**

(12) **EUROPEAN PATENT SPECIFICATION**

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

30.10.2024 Bulletin 2024/44

(21) Application number: **20737106.3**

(22) Date of filing: **26.06.2020**

(51) International Patent Classification (IPC):

F02M 65/00 ^(2006.01) **F02M 47/02** ^(2006.01)
F02M 61/12 ^(2006.01) **F02M 61/20** ^(2006.01)
F02M 57/00 ^(2006.01) **F02M 63/00** ^(2006.01)
F02M 61/18 ^(2006.01)

(52) Cooperative Patent Classification (CPC):

F02M 65/005; F02D 41/3005; F02M 47/027;
F02M 57/005; F02M 61/12; F02M 61/1873;
F02M 61/1893; F02M 61/205; F02M 63/0045;
F02D 41/20; F02D 2400/22; F02M 2200/28;
F02M 2547/003

(86) International application number:

PCT/EP2020/068160

(87) International publication number:

WO 2020/260666 (30.12.2020 Gazette 2020/53)

(54) **FUEL INJECTOR WITH CLOSED LOOP DETECTION**

KRAFTSTOFFINJEKTOR MIT ERKENNUNG VON GESCHLOSSENEM KREISLAUF

INJECTEUR DE COMBUSTIBLE À DÉTECTION EN CIRCUIT FERMÉ

(84) Designated Contracting States:

AL AT BE BG CH CY CZ DE DK EE ES FI FR GB
GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO
PL PT RO RS SE SI SK SM TR

(30) Priority: **27.06.2019 GB 201909257**

(43) Date of publication of application:

04.05.2022 Bulletin 2022/18

(73) Proprietor: **PHINIA Delphi Luxembourg SARL**

4367 Belvaux (LU)

(72) Inventors:

- **COCHET, Thierry**
41190 Valencisse (FR)
- **PERROT, Baptiste**
41000 Blois (FR)

• **TAPIN, Christophe**

41000 Saint Sulpice de Pommeray (FR)

• **BERLEMONT, Jean-François**

1310 La Hulpe (BE)

• **VIT, Romain**

41120 Chailles (FR)

(74) Representative: **Office Freylinger**

P.O. Box 48

8001 Strassen (LU)

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Description

FIELD OF THE INVENTION

[0001] The present invention generally relates to the field of fuel injection, in particular in internal combustion engines. The invention more particularly relates to fuel injectors featuring a closed loop detection function enabling detection of needle opening or closing.

BACKGROUND OF THE INVENTION

[0002] In a diesel fuel injector, the displacements of a valve member, or needle, between an open position and a closed position enable, or forbid, fuel injection through spray holes provided in the nozzle body of the injector. The needle is an elongated shaft-like member extending from a head portion, protruding in a control chamber, to a pointy extremity provided with a (moving) seating face that cooperates with a (fixed) seating face integral with the nozzle body. The needle is slideably guided in the nozzle body and, in closed position, the moving seating face is in sealing contact against the fixed seating face, thereby closing fluid communication to the spray holes and thus forbidding fuel injection. In open position the moving seating face is lifted away from the fixed seating face thus opening said fluid communication and enabling fuel injection through the spray holes.

[0003] In order to comply with emissions standards, a proper operation of a fuelinjected engine requires that the fuel injectors and their controller allow for a timely, precise and reliable fuel injection, whatever the operating condition and during all injector lifecycle.

[0004] It is now known that a major improvement in the control of fuel injection equipment and of the injection event is obtained with a so called closedloop control method. WO2017/167627, for example, discloses a fuel injector designed with a switch function for detecting needle opening and closing. The needle is axially guided in its upper region by a guide member that is set to a predetermined electric potential. The needle is mounted in the nozzle body so as to be able to move therein while being electrically isolated from the nozzle body, except for the region of the nozzle body seat, so that the needle is in electric contact with the nozzle body only in closed position.

[0005] More generally, closed loop control methods are typically executed by an electronic control unit (ECU) that controls the operation of the fuel injection equipment and in particular the control valve of the fuel injector. Depending on embodiments, the close loop means enable for an electrical signal to be measured at a specific value when the needle gets in closed position or the signal can also take a specific value when the needle is in fully open position. Overall, the closed loop detection function permits determining the injector opening time, and thus estimating the injected fuel quantity which is dependent on needle opening time and fuel pressure.

[0006] It has been observed that certain operating conditions may cause an erroneous detection of the needle opening. During early opening of the needle (i.e. within the first few microns of lift), cavitation may appear between the needle and the nozzle seat, leading to a hesitating electrical contact. Sometimes, the distance between the needle tip and valve seat is sufficient to open the electric link. Sometimes the distance is insufficient and the electric link remains closed due to the electric field. Still another possibility is that the needle tip deviates from its axis to be in contact with the seat, so that the electric link is closed. These phenomena are thus at the origin of an unstable switching signal.

[0007] Prior art fuel injectors are known from EP 1 528 251, DE 102011016168 and WO2016/208130.

OBJECT OF THE INVENTION

[0008] The object of the present invention is to provide a fuel injector of improved design, wherein stable closed loop detection signal is ensured.

[0009] This object is achieved by a fuel injector as claimed in claim 1.

SUMMARY OF THE INVENTION

[0010] According to the present invention, a fuel injector comprises:

a nozzle with a body extending along a main axis, the body having a peripheral wall defining an internal bore in which a needle is axially moveable, said nozzle having an end provided with one or more injection orifices to form a spray extremity;

wherein the needle extends along a needle axis and has an overall shape with symmetry of revolution about the needle axis, the needle comprising a shaft portion which is tapered at a first end and defines a male seating face that cooperates with a female tapered seating face in the bore, upstream of the injection orifice(s), such that in a closed state, the male seating face sealingly engages the female seating face to prevent fuel injection through the injection orifice(s), and such that in an open state, the needle is lifted from the female seating to allow fuel injection;

wherein the needle includes a protruding annular collar that divides the internal volume of the bore in an upstream chamber, wherein in use, pressurized fuel flows in, and a downstream chamber provided with the injection orifice(s);

a control chamber associated with a control valve arrangement, the control valve arrangement allowing to selectively vary, in use, a fuel pressure in the control chamber and thereby control an opening or closing move of the needle, the control valve ar-

rangement configured to be actuated by an actuator;

wherein the fuel injector further includes a detection circuit in which the needle forms a switch;

wherein the female tapered seating face is generally conical, the male tapered seating face including a conical surface having an angle greater than 75°;

the collar includes substantially symmetrically configured passage means for allowing fuel to flow from the upstream chamber to the downstream chamber; and

the control valve arrangement is configured as a three-way valve.

[0011] The present injector is designed to address the problem of needle lift hesitations at injector opening, which leads to unstable electrical switching of the detection circuit. According to the invention, this problem is solved by an injector design that is designed to promote a symmetrical rising of the needle at lift-off, thereby avoiding radial deviations and hence side contacts with the seat. This is obtained by a synergistic effect of a combination of design features, namely:

- the needle has excellent symmetry. In particular, the passage means in the collar separating the upstream and downstream chambers must be symmetrically designed, either as internal bores or peripheral grooves.
- the male seating face has a conical or frustoconical surface with an angle above 75°. This provides a wider surface area exposed to fuel pressure and limits the axial extent of the nozzle tip. Such wide seat angle also reduces restriction for low needle lift and thus improves fuel flow. Furthermore, preliminary tests show that for a same seat diameter (at seat line), the use of a widened seat angle is less sensitive to horizontal misalignment and to vertical rotation.
- the control valve arrangement is configured as a three-way valve. Such valve allows separately controlling the filling and discharge of the control chamber. In particular, it makes it possible to have a faster discharge of the control chamber, and thus to obtain a high speed needle opening.

[0012] The control valve arrangement includes a fuel escape path connecting the control chamber to a low pressure side of the injector and that can be selectively opened and closed; and a fuel feed path connecting the control chamber to a high pressure side of the injector and that can be selectively opened and closed. The fuel escape path includes a spill orifice (SPO) and the fuel feed path includes an inlet orifice (INO), the spill orifice defining a flow cross-section larger than that of the inlet orifice.

[0013] The passage means may include two or more through bores or peripheral grooves in the collar that have same dimensions and are circumferentially distributed with equal spacing. Preferably, the passage means include a calibrated orifice.

[0014] In practice, the male seating surface may have a cone angle in the range]75°; 110°], in particular [80°; 90°]. These values are considered as particularly appropriate for hydraulic controllability.

[0015] The injector is preferably designed so that in closed state, the male seating face engages the female seating face along a substantially circular seat line. In embodiments, the seat line corresponds to an annular edge at the transition between the male seating section and an upstream contiguous conical section.

[0016] Advantageously, the seat line has a diameter D_s in the range $1.4 \text{ mm} \leq D_s < 1.7 \text{ mm}$. Such seat diameter, which is reduced compared to standard designs, is desirable to reduce suction effect while still allowing proper hydraulic controllability. A reduced seat diameter also proves to be less sensitive to vertical rotation.

[0017] In embodiments, the needle opening speed can be further increased by providing marks on the surface of the needle tapered end that are positioned adjacent to the seat line, positioned above and/or below the latter. These marks may typically include a plurality of indents, slots and/or flats regularly distributed circumferentially.

[0018] In embodiments, the marks include: a set of slots having axial length of between 100 and 200 μm , a width of between 50 and 70 μm and a depth of between 6 and 10 μm ; or flats having an axial length of between 100 and 200 μm , and a depth of between 8 and 12 μm , the depending on the depth of the flat.

[0019] The marks above the seat line may be spaced 1 to 20 μm therefrom. Marks below the seat line may be spaced 50 to 200 μm therefrom.

BRIEF DESCRIPTION OF THE DRAWINGS

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

Figure 1: is a cross-section view through a fuel injector according to a first embodiment of the invention;

Figure 2: is a sketch of the needle tip design;

Figure 3: is a principle diagram of the control valve arrangement and hydraulic circuit of the injector; and

Figure 4: is a sketch of the nozzle tip.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0021] In reference to Figure 1 is now described a die-

sel fuel injector 10 having a general elongated shape extending along a main axis A and comprising, from bottom to top, a nozzle assembly 12, a control valve arrangement 14 and an actuator assembly 16. These assemblies are fixed to each other via a capnut 15. The actuator assembly 16 and control valve arrangement 14 are simply indicated by boxes in the figures; their operating principle will be described with reference to Fig. 3.

[0022] The injector 10 defines an internal high pressure fuel circuit comprising several segments and extending from an inlet section 18 provided in the upper part of the injector to spray holes 20 arranged in a lower spray extremity 22, also referred to as nozzle tip or injector tip, drawn at the very bottom of the injector 10.

[0023] The nozzle assembly 12 comprises a nozzle body 24 having a peripheral wall 26 defining an inner bore 28 in which is slideably arranged a needle 30, forming the valve member, and adapted to translate along the main axis A between a closed position CP and an open position OP that correspond to a closed and open state of the injector, respectively.

[0024] The needle valve member 30 has an elongated shaft core 32 extending (along needle axis concentric with axis A) between a top head end 33 and a lower end with a tapered tip 34. In between the ends, the needle 30 is provided with a radially protruding collar member 36 that extends toward a circular edge that lies close to the inner face of the inner bore 28 of the nozzle body 26. The collar member 36 divides the inner bore 28 into an upstream chamber 38 and a downstream chamber 40. A permanently open fluid communication is defined between these chambers by flow passage means provided in the collar member 36, or at the periphery of it or, along the circular edge. Reference sign 42 designates a guide collar similar to collar member 36 to guide the needle 30 in the lower region of bore 28. The needle is biased in closed position by a spring 31.

[0025] The spray extremity 22 is the arrangement of the tapered end 34 of the needle 30 defining a male needle seating face 44 cooperating with a corresponding female nozzle seating face 46 defined on the inner face of the nozzle body 24. The nozzle seating face 46 is annular and surrounds the inner bore 28, upstream of the spray orifices 20. The needle seating face 44 is also said to be mobile because it moves with the needle, whereas the nozzle seating face 46 is referred to as fixed seating face. In the spray extremity 22, the inner bore 28 that is cylindrical, downwardly narrows forming said female nozzle seating face 46 ending in a small sac 48 (closed end) wherefrom depart the spray holes 20 extending through the peripheral wall 26 of the nozzle body 24.

[0026] As is known in the art, in the closed position (CP) of the needle 30 - illustrated in Fig. 1- the male seating face 44 rests sealingly on the female seating face 46 and fuel flow towards the spray orifices 20 is prevented. An open position (OP) of the needle 30 is a position where the needle 30 is off the valve seat, i.e. there is a space between the male seating face 44 and female seat-

ing face 46, whereby fuel can flow through this space downstream of the valve seat to the spray orifices 20, so that fuel is sprayed at the injector tip into the combustion chamber.

[0027] Actuation of the needle 30 is performed by energizing the actuator assembly 16, typically a solenoid that acts on a valve member of the control valve arrangement 14. The control valve arrangement 14 is conventionally connected with a control chamber 50 at the top of the nozzle assembly 12, in which the needle head 33 (opposite tip 34) protrudes. Energizing the actuator 16 will thus cause triggering of the control valve (connected to a mobile armature of the solenoid actuator) that will open an escape path for fuel out of control chamber 50. This will cause a decrease of pressure in the control chamber 50, whereby needle 230 will move upward into the control chamber in OP and thus open the valve seat. This principle of operation is well known.

[0028] Fuel injector 10 further comprises a detection circuit for detecting needle opening and closing, which is also referred to as closed loop. In the present embodiment, this is achieved by a simple switch function. The needle 30 is axially guided in its upper region by a guide member 54 that is set to a predetermined electric potential. The guide member 54 has an axial bore in which the needle head 33 is received. The needle 30 is mounted in the nozzle body 24 so as to be able to move therein while being electrically isolated from the nozzle body 24, except for the region of the nozzle body seat 46, so that the needle 30 is in electric contact with the nozzle body 24 only in CP. The needle 30 is electrically insulated from the body 24 by means of insulating sheeting or coatings indicated 56 provided at the collars 40, 42 and at the interface with the guide member 54.

[0029] When the needle is in CP, the circuit is closed and an electric current can flow from the upper guide 56 through the length of the needle 30 to pass into the body 24 at the needle tip in contact with the female seating face 46. This detection circuit and flow path is indicated by line 58 in Fig. 1. When the needle 30 is in OP, the detection circuit is open and no current can flow to the body 24. There, in CP the voltage may thus be 0 V whereas in OP the circuit is open a predetermined voltage, e.g. 5 V is measured. This is only one way of performing closed loop detection and a variety of voltages and designs may be used, e.g. including detection of the fully open needle position, as will be clear to those skilled in the art.

[0030] It shall be appreciated that the design of the present injector has been improved in order to ensure a clean electric contact at opening or closing of the needle 30.

[0031] A first aspect of the design is the shape of the needle tip 34. The male seating face 44 here is a conical section that has a wide tip angle, namely of more than 75°, in particular in the range 75° to 120°, and more specifically in the range 80° to 110°, or 80° to 90°. The use of a wide tip angle reduces the overall length of the tip

portion and results in a larger annular gap relative to the nozzle body 24. It will be appreciated that this design is less sensitive to misalignment and thus less critical to needle guidance.

[0032] Fig.2 is a sketch representing needle tip design, the needle being in CP. One will recognize the tapered extremity 34 of the needle and the cooperating needle body female seating face 46. Both male and female seating faces are designed as annular surfaces having a geometry of revolution (i.e. circular symmetry) around axis A.

[0033] The needle tip includes a male seating face 44 that is configured as a conical surface and has a cone angle noted β . In the present case, the male seating face 44 has a full conical shape, with a single angle β . In other embodiments, the male seating face 44 may simply be a frustoconical section, and the portion closer to the terminal portion of the needle can have one or more sections with different cone angles and/or can even exhibit a truncated end.

[0034] Above the seating face 44 is an upstream frustoconical section 34.1 of narrower cone angle. The intersection between the male seating face 44 and upstream section 34.1 forms an annular line 45 that represents the theoretical seat line between the needle male seating face 44 and the female seating face 46. Contiguous to the upstream section 34.1, in direction of the needle head, is an intermediate cylindrical section 34.2, directly followed by a conical section 34.3 broadening up to the diameter of the needle core.

[0035] The angle of the female conical section 46 is preferably slightly smaller than that of the male seating face 44, e.g. 0.5 to 3. The female seating is located in inner bore 28 at the appropriate position to be engaged by the male seating face 44 and thus has a certain axial extent below and above the desired position of seat line 45 in CP. In Fig.2 the female seating face 46 has a long axial extent with a single cone angle. In other embodiments, the profile of the inner bore at the nozzle tip may vary, and have one or several different shapes, e.g. in the sac 48 region or further above the seat line 45.

[0036] The cone angles below the seat line 45 (i.e. angle β) and above the seat line 45 are slightly different from the cone angle of the female seating face 46, so that there is an upper differential angle noted $\delta 1$ and a lower differential angle noted $\delta 2$.

[0037] Another remarkable aspect of the injector 10 is the design of the collar 36, which includes symmetrically designed flow passage means. Indeed, the flow passages for the fuel from the upstream chamber 38 to downstream chamber 40 must be symmetrically designed to ensure a force balance around the axis and avoid generating some transverse bias. Where the flow passage means include through holes 36.1, there is a number of at least two through holes 36.1. The through holes 36.1 extend from the upper to the lower face of the collar 36, have same internal diameter, and are circumferentially regularly spaced. In other words, in the present variant

two through holes 36.1 are here located opposite one another (spaced by 180°). In case of three through holes, they are spaced by 120° , and four through holes are spaced by 90° , etc. The passage means can also be designed as external passages, by providing peripheral grooves extending from the upper to the lower face, parallel or slanted along axis A. Here also the grooves are regularly spaced at the periphery to ensure a homogeneous force balance. Another alternative is to provide an annular radial clearance to have the desired flow rate.

[0038] A third aspect of the present injector is that the control valve arrangement 14 is designed as a three-way valve. The principle here is that there is a return flow path with a spill orifice, noted SPO, and a feed flow path with an inlet orifice, noted INO, that can be independently controlled. The spill orifice SPO has a larger flow cross-section than the inlet orifice INO in order to enable a rapid emptying of the control chamber 50. This results in an increase in needle opening speed.

[0039] Fig.3 is a principle drawing illustrating a possible embodiment of hydraulic circuit within the present injector 10, where the valve arrangement 14 is designed as three-way valve. One will recognize the injector needle 30 with its tip 34 and head 33 in control chamber 50.

[0040] Reference sign 60 designates the valve member of the control valve arrangement 14, which is movable in a valve chamber 62. Valve member 60 is connected by a shaft 64 to a magnetic armature 66 facing the actuator 16, which is here simply represented by its magnetic coil 68. Energizing the magnetic coil 68 will attract the armature 66 to empty the control chamber 62, thereby causing the needle 30 to move in the nozzle body towards its OP in which the male seat 44 is lifted off the female seat 46, hence allowing spraying of fuel through orifices 20. The nozzle head 33 comes into abutment against the ceiling of the control chamber 50.

[0041] When the injector is powered off, the control valve member 60 returns to its initial position, closing the leakage so that fuel flowing into the control chamber 62 remains therein. Pressure in the control chamber 50 progressively builds up, and the needle 30, pushed by the fuel and spring 31 force, moves into the CP, in which the male seating 44 is in sealed engagement with the female seating 46. Fuel injection is stopped.

[0042] The valve chamber includes a first (upper) seat 70 and second (lower) seat X. A HP channel 72, in communication with the HP supply 18, arrives at the upper seat 70. The lower seat 74 opens into a return channel 76 connecting to the low pressure fuel return circuit.

[0043] High pressure fuel is supplied via a fuel feed patch formed by first channel 78 branched off from channel 72 and comprising a calibrated inlet orifice INO.

[0044] Reference sign 80 designates a second channel that connects directly into the valve chamber 62 and comprises a calibrated spill orifice SPO to control the leakage rate of fuel flowing out of the control chamber 50. The second channel forms a fuel escape path.

[0045] The first and second channels merge into an

intermediate channel 82 that opens into the control chamber 50, although they could be individually connected.

[0046] Fig.3 shows the active configuration of the injector. The actuator is energized and the control valve member rests on the upper seat 70. The lower seat 74 is thus open, allowing fuel to flow from the control chamber 50 to the low pressure side of the injector.

[0047] Stopping the current through the injector coil 68 will cause the valve member 60 to return to its default configuration, in which the lower seat 74 is closed by valve member 60. The fuel in the control chamber 62 can no longer escape through lower seat 74. Pressure builds up in control chamber 50 and the needle returns to its seat, closing the injector.

[0048] In the present design, the SPO and NPO have different flow crosssections, and specifically the cross-section of the SPO is larger than that of the NPO, e.g. at least 1.5 or 2 times the NPO diameter.

[0049] Independent control of the filling and emptying flows allows a better control of injector behavior. The present design permits a faster emptying of the control chamber, resulting in an increased needle opening speed.

[0050] Altogether, the three above mentioned features of the injector act synergistically to promote a prompt and straight/axial lifting of the needle, thereby avoiding oscillations or random needle behavior that may be observed under certain conditions. Accordingly, the seat detection circuit operates a clean switching from the closed to the open state as the needle starts lifting and leaves the female seating, leading to a stable electric signal.

[0051] An option to further increase the needle opening speed is to provide symmetrically arranged marks on the needle tip, in the vicinity of the seat line 45, i.e. below and/or above the seat line 45. Figure 4 represents schematically the needle tip with the seat line delimitating the seating surface 44 from the upstream frustoconical section 34.1.

[0052] These marks take the form of indents or notches obtained by machining. The resulting material removal reduces flow restriction for low needle lift and thus improves fuel flow. The marks may particular be provided by machining axial slots or flats. Axial slots located below the seat line 45 are designated 90 in fig.4, whereas axial slots located above the seat line 45 are designated 92. The slots are circumferentially regularly distributed, i.e. separated by an equal distance $e1$.

[0053] Good results have been obtained with a series of a dozen slots extending axially, having a width of 60 μm (tangential direction) and a depth of 8 μm (radial direction), or with a set of 8 flats having a depth of about 10 μm .

[0054] Marks, namely flats or slots, located above the seat line are preferably positioned at a distance $d1$ between 1 and 20 μm from the seat line.

[0055] Marks, namely flats or slots, located below the seat line are preferably positioned at a distance $d2$ between 50 and 200 μm from the seat line.

[0056] Still a further parameter that can be optimized to improve needle stability at opening is the diameter, which can advantageously be reduced compared to conventional design. In particular, the seat diameter, i.e. the diameter at the seat line, noted D_s , lies preferably within the following range: $1.4 \text{ mm} \leq D_s < 1.7 \text{ mm}$.

[0057] A seat diameter D_s within the abovementioned ranges allows for hydraulic stability while reducing suction effects at lift off.

Claims

1. A fuel injector comprising:

a nozzle (12) with a body (24) extending along a main axis, said body having a peripheral wall (26) defining an internal bore (28) in which a needle (30) is axially moveable, said nozzle having an end provided with one or more injection orifices (20) to form a spray extremity; wherein said needle extends along a needle axis (A) and has an overall shape with symmetry of revolution about said needle axis (A), said needle comprising a shaft portion (32) which is tapered at said first end (34) and defines a male seating face (44) that cooperates with a female tapered seating face (46) in said bore (28), upstream of said injection orifice(s), such that in a closed state, said male seating face (44) sealingly engages said female seating face (46) to prevent fuel injection through said injection orifice(s), and such that in an open state, said needle is lifted from said female seating to allow fuel injection; wherein said needle (30) includes a protruding annular collar (36) that divides the internal volume of said bore (28) in an upstream chamber (38), wherein in use, pressurized fuel flows in, and a downstream chamber (40) provided with said injection orifice(s); a control chamber (50) associated with a control valve arrangement (14), said control valve arrangement allowing to selectively vary, in use, a fuel pressure in said control chamber (50) and thereby control an opening or closing move of said needle (30), said control valve arrangement configured to be actuated by an actuator (16); wherein said fuel injector further includes a detection circuit (58) in which said needle (30) forms a switch; wherein said female tapered seating face (46) is generally conical, said male tapered seating face (44) including a conical surface having an angle (β) greater than 75° ; said collar (36) includes substantially symmetrically configured passage means (36.1) for allowing fuel to flow from said upstream chamber

(38) to said downstream chamber (40); and said control valve arrangement (14) is configured as a three-way valve; wherein said control valve arrangement (14) includes:

a fuel escape path (80) connecting the control chamber (50) to a low pressure side of the injector and that can be selectively opened and closed; and
a fuel feed path (78) connecting the control chamber (50) to a high pressure side of the injector and that can be selectively opened and closed; and

wherein said fuel escape path includes a spill orifice (SPO) and said fuel feed path includes an inlet orifice (INO), said spill orifice (SPO) defining a larger flow cross-section than said inlet orifice.

2. The fuel injector as claimed in any one of the preceding claims, wherein said passage means includes two or more through bores (36.1) or peripheral grooves in said collar that are circumferentially distributed with equal spacing.
3. The fuel injector as claimed in claim 2, wherein said passage means include a calibrated orifice.
4. The fuel injector as claimed in any one of the preceding claims, wherein said male seating surface (44) has a cone angle (β) in the range $]75^\circ; 110^\circ]$, in particular $[80^\circ; 90^\circ]$.
5. The fuel injector as claimed in any one of the preceding claims, wherein in said closed state, said male seating face engages said female seating face along a substantially circular seat line (45).
6. The fuel injector as claimed in claim 5, wherein said seat line (45) corresponds to an annular edge at the transition between the male seating section (44) and an upstream contiguous conical section (34.1).
7. The fuel injector as claimed in claim 5 or 6, wherein said seat line (45) has a diameter D_s in the range: $1.4 \text{ mm} \leq D_s < 1.7 \text{ mm}$.
8. The fuel injector as claimed in any one of the preceding claims, comprising marks (90, 92) provided on the surface of said needle tapered end positioned adjacent said seat line (45), positioned above and/or below the latter.
9. The fuel injector as claimed in claim 8, wherein said marks (90, 92) include a plurality of indents, slots and/or flats regularly distributed circumferentially.

10. The fuel injector as claimed in claim 9, wherein said marks include:

a set of slots having axial length of between 100 and 200 μm , a width of between 50 and 70 μm and a depth of between 6 and 10 μm ; or
flats having an axial length of between 100 and 200 μm , and a depth of between 8 and 12 μm .

11. The fuel injector as claimed claim 8, 9 or 10, wherein marks above said seat line are spaced 1 to 20 μm therefrom, and marks below said seat line are spaced 50 to 200 μm therefrom.

Patentansprüche

1. Einspritzventil, umfassend:

eine Düse (12) mit einem Körper (24), der sich entlang einer Hauptachse erstreckt, wobei der Körper eine Umfangswand (26) aufweist, die eine Innenbohrung (28) definiert, in der eine Nadel (30) axial beweglich ist, wobei die Düse ein Ende aufweist, das mit einer oder mehreren Einspritzöffnungen (20) versehen ist, um eine Sprühende zu bilden;

wobei sich die Nadel entlang einer Nadelachse (A) erstreckt und eine Gesamtform mit Rotationssymmetrie um die Nadelachse (A) aufweist, wobei die Nadel einen Schaftabschnitt (32) umfasst, der an dem ersten Ende (34) verjüngt ist und eine männliche Auflagefläche (44) definiert, die mit einer weiblichen verjüngten Auflagefläche (46) in der Bohrung (28) zusammenwirkt, stromaufwärts der Einspritzöffnung(en), so dass in einem geschlossenen Zustand die männliche Auflagefläche (44) abdichtend an der weiblichen Auflagefläche (46) anliegt, um eine Kraftstoffeinspritzung durch die Einspritzöffnung(en) zu verhindern, und in einem offenen Zustand die Nadel von der weiblichen Auflagefläche abgehoben wird, um eine Kraftstoffeinspritzung zu ermöglichen;

wobei die Nadel (30) einen vorstehenden ringförmigen Kragen (36) aufweist, der das Innenvolumen der Bohrung (28) in eine stromaufwärts gelegene Kammer (38), in die im Betrieb unter Druck stehender Kraftstoff einströmt, und eine stromabwärts gelegene Kammer (40), die mit der/den Einspritzöffnung(en) versehen ist, unterteilt;

eine Steuerkammer (50), die mit einer Steuerventilanordnung (14) verbunden ist, wobei die Steuerventilanordnung es ermöglicht, im Betrieb einen Kraftstoffdruck in der Steuerkammer (50) selektiv zu variieren und dadurch eine Öffnungs- oder Schließbewegung der Nadel (30)

zu steuern, wobei die Steuerventilanordnung so konfiguriert ist, dass sie von einem Stellglied (16) betätigt wird;

wobei das Einspritzventil ferner einen Erfassungskreis (58) aufweist, in dem die Nadel (30) einen Schalter bildet;

wobei die weibliche verjüngte Auflagefläche (46) im Allgemeinen konisch ist und die männliche verjüngte Auflagefläche (44) eine konische Oberfläche mit einem Winkel (β) von mehr als 75° aufweist;

der Kragen (36) eine im Wesentlichen symmetrisch gestaltete Durchgangseinrichtung (36.1) aufweist, die es ermöglicht, dass Kraftstoff von der stromaufwärts gelegenen Kammer (38) zu der stromabwärts gelegenen Kammer (40) fließt; und

die Steuerventilanordnung (14) als Dreiwegeventil ausgebildet ist;

wobei die Steuerventilanordnung (14) Folgendes umfasst:

einen Kraftstoffaustrittsweg (80), der die Steuerkammer (50) mit einer Niederdruckseite des Einspritzventils verbindet und der selektiv geöffnet und geschlossen werden kann; und
einen Kraftstoffzufuhrweg (78), der die Steuerkammer (50) mit einer Hochdruckseite des Einspritzventils verbindet und der selektiv geöffnet und geschlossen werden kann; und
wobei der Kraftstoffaustrittsweg eine Überlauföffnung (SPO) und der Kraftstoffzufuhrweg eine Einlassöffnung (INO) aufweist, wobei die Überlauföffnung (SPO) einen größeren Strömungsquerschnitt als die Einlassöffnung definiert.

2. Einspritzventil nach einem der vorhergehenden Ansprüche, wobei die Durchgangseinrichtung zwei oder mehr Durchgangsbohrungen (36.1) oder Randnuten in dem Kragen aufweist, die in Umfangsrichtung mit gleichen Abständen verteilt sind.

3. Einspritzventil nach Anspruch 2, wobei die Durchgangseinrichtung eine kalibrierte Öffnung aufweist.

4. Einspritzventil nach einem der vorhergehenden Ansprüche, wobei die männliche Auflagefläche (44) einen Konuswinkel (β) im Bereich $[75^\circ; 110^\circ]$, insbesondere $[80^\circ; 90^\circ]$, aufweist.

5. Einspritzventil nach einem der vorhergehenden Ansprüche, wobei im geschlossenen Zustand die männliche Auflagefläche an der weiblichen Auflagefläche entlang einer im Wesentlichen kreisförmigen Sitzlinie (45) anliegt.

6. Einspritzventil nach Anspruch 5, wobei die Sitzlinie

(45) einer ringförmigen Kante am Übergang zwischen dem männlichen Auflageabschnitt (44) und einem stromaufwärts angrenzenden konischen Abschnitt (34.1) entspricht.

7. Einspritzventil nach Anspruch 5 oder 6, wobei die Sitzlinie (45) einen Durchmesser D_s in dem Bereich aufweist: $1,4 \text{ mm} \leq D_s < 1,7 \text{ mm}$.

8. Einspritzventil nach einem der vorhergehenden Ansprüche, welches Markierungen (90, 92) aufweist, die an der Oberfläche des verjüngten Endes der Nadel so bereitgestellt sind, dass sie benachbart zur Sitzlinie (45) positioniert sind, oberhalb und/oder unterhalb der Sitzlinie.

9. Einspritzventil nach Anspruch 8, wobei die Markierungen (90, 92) eine Vielzahl von Einkerbungen, Schlitzten und/oder Abflachungen umfassen, die regelmäßig umlaufend verteilt sind.

10. Einspritzventil nach Anspruch 9, wobei die Markierungen umfassen:

einen Satz von Schlitzten mit einer axialen Länge zwischen 100 und 200 μm , einer Breite zwischen 50 und 70 μm und einer Tiefe zwischen 6 und 10 μm ;
oder Abflachungen mit einer axialen Länge zwischen 100 und 200 μm und einer Tiefe zwischen 8 und 12 μm .

11. Einspritzventil nach Anspruch 8, 9 oder 10, wobei die Markierungen oberhalb der Sitzlinie in einem Abstand von 1 bis 20 μm zu dieser und die Markierungen unterhalb der Sitzlinie in einem Abstand von 50 bis 200 μm zu dieser angeordnet sind.

Revendications

1. Injecteur de combustible comprenant :

une buse (12) comportant un corps (24) étendu suivant un axe principal, ledit corps comportant une paroi périphérique (26) définissant un alésage interne (28) dans lequel un pointeau (30) peut être déplacé axialement, ladite buse comportant une partie terminale munie d'un ou de plusieurs orifices d'injection (20) pour former une extrémité de pulvérisation ;

dans lequel ledit pointeau est étendu suivant un axe de pointeau (A) et présente une forme globale à symétrie de révolution autour dudit axe de pointeau (A), ledit pointeau comprenant une partie d'arbre (32) qui est effilée au niveau de ladite première partie terminale (34) et qui définit une face d'assise mâle (44) qui coopère avec

une face d'assise effilée femelle (46) dans ledit alésage (28), en amont dudit/desdits orifice(s) d'injection, de telle sorte que dans un état fermé, ladite face d'assise mâle (44) engage de façon étanche ladite face d'assise femelle (46) pour empêcher une injection de combustible au travers dudit/desdits orifice(s) d'injection et de telle sorte que dans un état ouvert, ledit pointeau soit relevé par rapport à ladite face d'assise femelle pour permettre l'injection de combustible ; dans lequel ledit pointeau (30) inclut un collier annulaire en saillie (36) qui divise le volume interne dudit alésage (28) selon une chambre amont (38), à l'intérieur de laquelle, en utilisation, du combustible sous pression s'écoule, et selon une chambre aval (40) qui est munie dudit/desdits orifice(s) d'injection ; une chambre de commande (50) associée à un agencement de soupape de commande (14), ledit agencement de soupape de commande permettant de faire varier de manière sélective, en utilisation, une pression de combustible dans ladite chambre de commande (50) et d'ainsi commander un déplacement d'ouverture ou de fermeture dudit pointeau (30), ledit agencement de soupape de commande étant configuré pour être activé par un actionneur (16) ; dans lequel ledit injecteur de combustible inclut en outre un circuit de détection (58) dans lequel ledit pointeau (30) forme un commutateur ; dans lequel ladite face d'assise effilée femelle (46) est de forme générale conique, ladite face d'assise effilée mâle (44) incluant une surface conique présentant un angle (β) supérieur à 75° ; ledit collier (36) inclut un moyen de passage configuré de façon sensiblement symétrique (36.1) pour permettre l'écoulement du combustible depuis ladite chambre amont (38) jusqu'à ladite chambre aval (40) ; et ledit agencement de soupape de commande (14) est configuré en tant que soupape à trois voies ; dans lequel ledit agencement de soupape de commande (14) inclut :

un passage d'échappement de combustible (80) qui connecte la chambre de commande (50) à un côté basse pression de l'injecteur et qui peut être sélectivement ouvert et fermé ; et
un passage d'alimentation en combustible (78) qui connecte la chambre de commande (50) à un côté haute pression de l'injecteur et qui peut être sélectivement ouvert et fermé ; et
dans lequel ledit passage d'échappement de combustible inclut un orifice de déverse-

ment (SPO) et ledit passage d'alimentation en combustible inclut un orifice d'entrée (INO), ledit orifice de déversement (SPO) définissant une section en coupe transversale d'écoulement plus grande que ledit orifice d'entrée.

2. Injecteur de combustible tel que revendiqué selon la revendication précédente, dans lequel ledit moyen de passage inclut deux alésages traversants ou plus (36.1) ou deux rainures ou gorges périphériques ou plus dans ledit collier qui sont distribuées de façon circconférentielle selon un espacement égal.
3. Injecteur de combustible tel que revendiqué selon la revendication 2, dans lequel ledit moyen de passage inclut un orifice calibré.
4. Injecteur de combustible tel que revendiqué selon l'une quelconque des revendications précédentes, dans lequel ladite face d'assise mâle (44) présente un angle de cône (β) dans la plage de $[75^\circ ; 110^\circ]$, en particulier dans la plage de $[80^\circ ; 90^\circ]$.
5. Injecteur de combustible tel que revendiqué selon l'une quelconque des revendications précédentes, dans lequel, dans ledit état fermé, ladite face d'assise mâle engage ladite face d'assise femelle suivant une ligne de siège sensiblement circulaire (45).
6. Injecteur de combustible tel que revendiqué selon la revendication 5, dans lequel ladite ligne de siège (45) correspond à un bord annulaire au niveau de la transition entre la section d'assise mâle (44) et une section conique contiguë amont (34.1).
7. Injecteur de combustible tel que revendiqué selon la revendication 5 ou 6, dans lequel ladite ligne de siège (45) présente un diamètre D_s dans la plage suivante : $1,4 \text{ mm} \leq D_s < 1,7 \text{ mm}$.
8. Injecteur de combustible tel que revendiqué selon l'une quelconque des revendications précédentes, comprenant des marques (90, 92) qui sont apposées sur la surface de ladite partie terminale effilée de pointeau en une position adjacente à ladite ligne de siège (45), en une position au-dessus et/ou au-dessous de cette dernière.
9. Injecteur de combustible tel que revendiqué selon la revendication 8, dans lequel lesdites marques (90, 92) incluent une pluralité d'indentations, de fentes et/ou de méplats distribuées de façon circconférentielle.
10. Injecteur de combustible tel que revendiqué selon la revendication 9, dans lequel lesdites marques incluent :

un ensemble de fentes présentant une longueur axiale entre 100 et 200 μm , une largeur entre 50 et 70 μm et une profondeur entre 6 et 10 μm ;
ou

des méplats présentant une longueur axiale entre 100 et 200 μm et une profondeur entre 8 et 12 μm .

11. Injecteur de combustible tel que revendiqué selon la revendication 8, 9 ou 10, dans lequel les marques au-dessus de ladite ligne de siège sont espacées de celle-ci de 1 à 20 μm et les marques au-dessous de ladite ligne de siège sont espacées de celle-ci de 50 à 200 μm .

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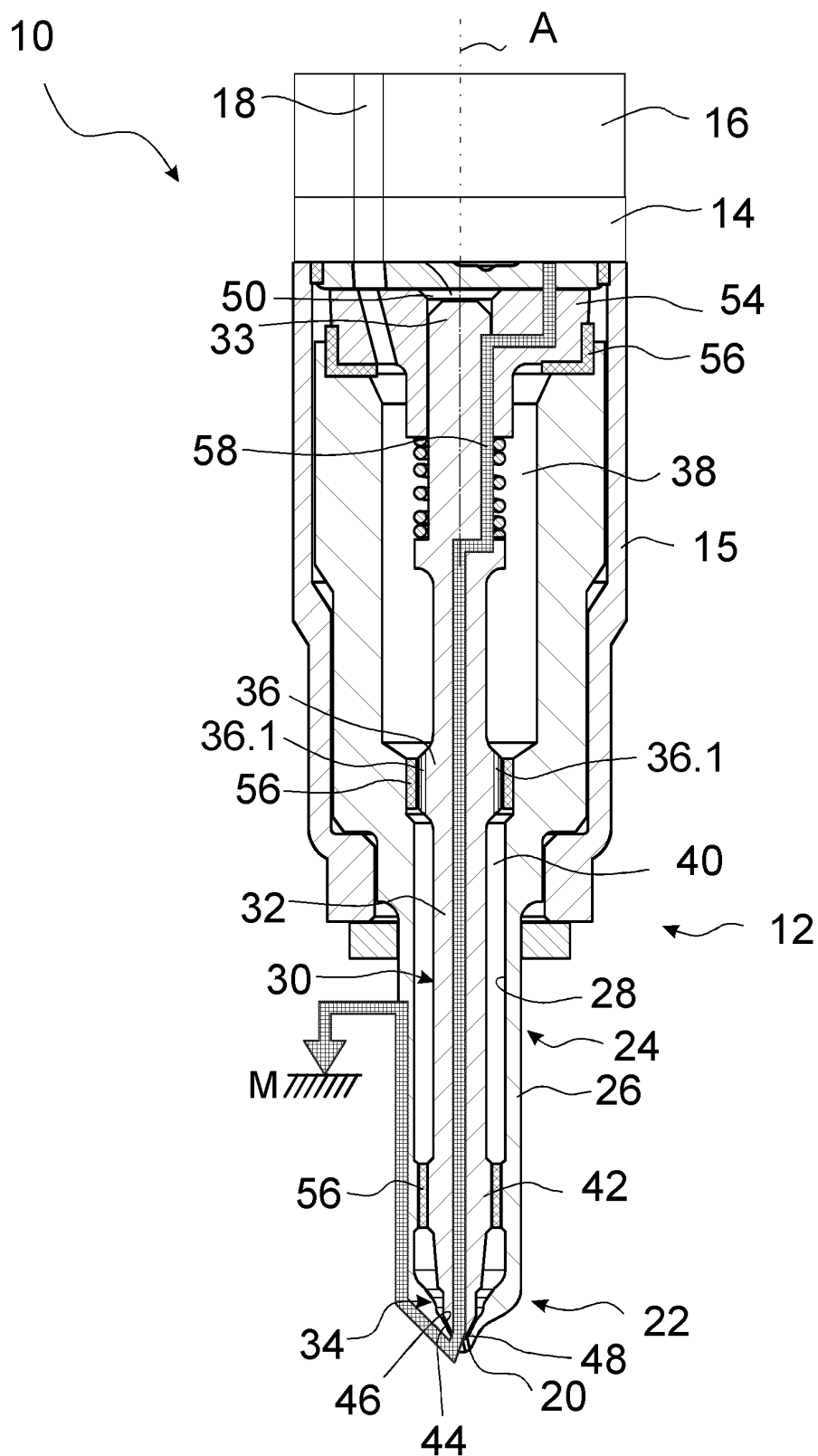
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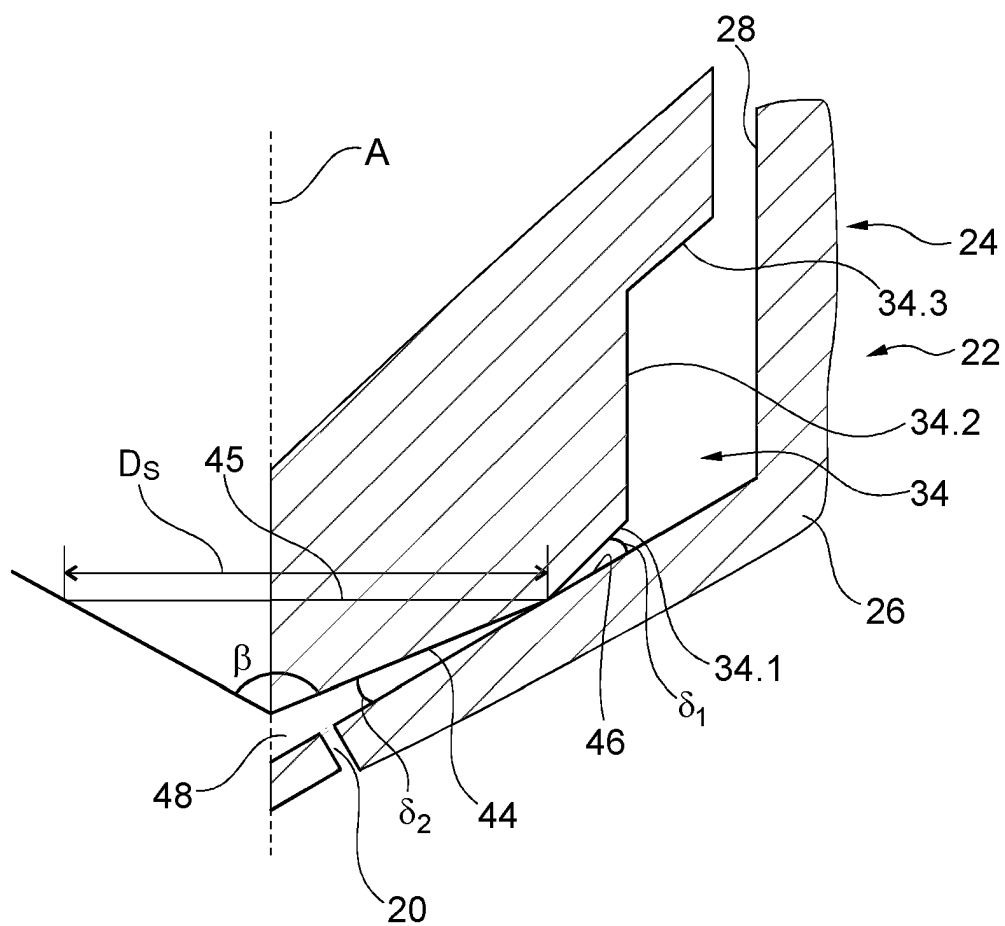


Fig. 2

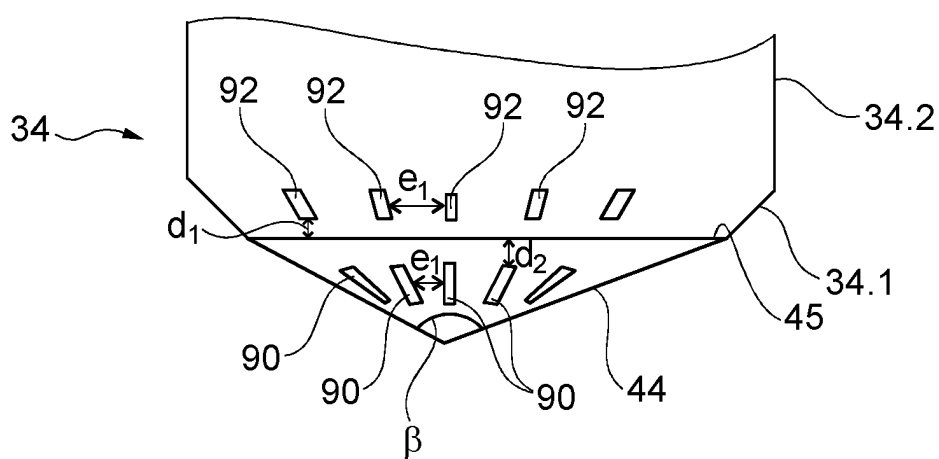


Fig. 4

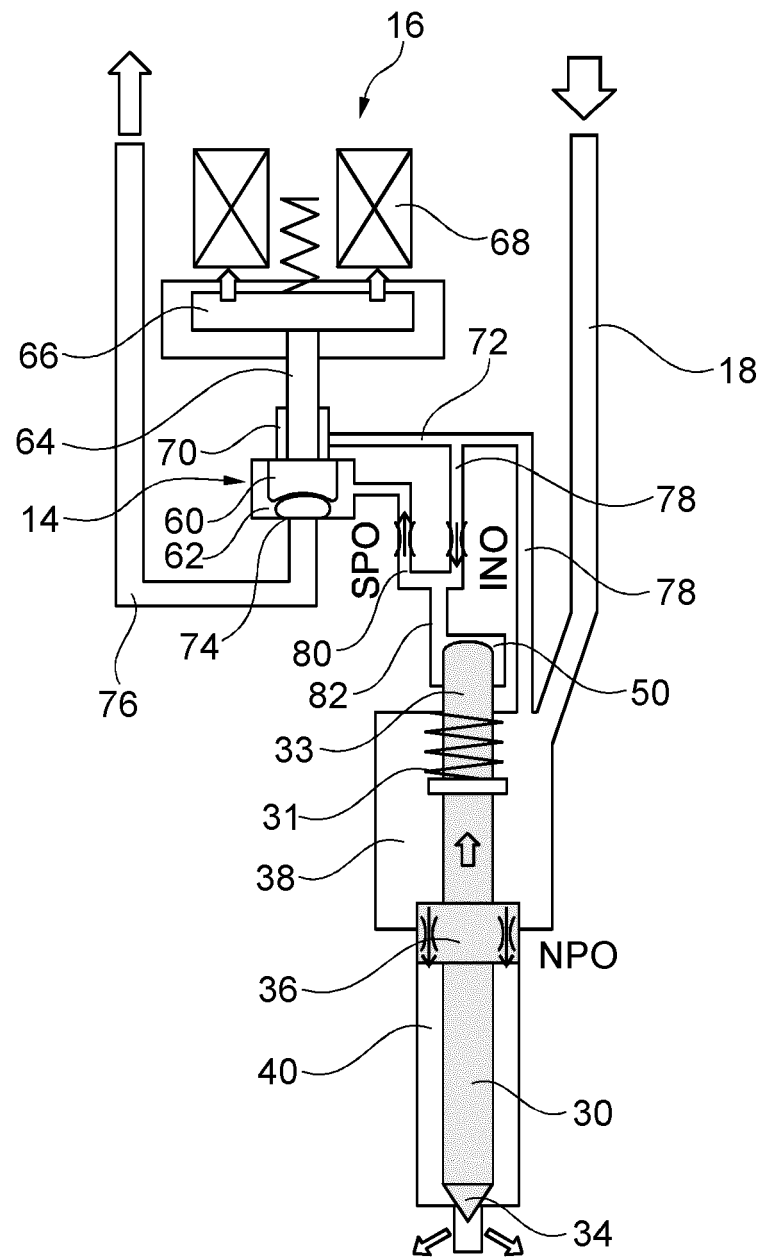


Fig. 3

REFERENCES CITED IN THE DESCRIPTION

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