



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
11.10.2017 Bulletin 2017/41

(51) Int Cl.:
F02M 47/02 (2006.01) **F02M 57/00** (2006.01)
F02M 61/12 (2006.01) **F02M 61/16** (2006.01)
F02M 65/00 (2006.01) **F02M 63/00** (2006.01)

(21) Application number: **17162433.1**

(22) Date of filing: **22.03.2017**

(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
Designated Extension States:
BA ME
Designated Validation States:
MA MD

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(30) Priority: **04.04.2016 GB 201605656**

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(54) **FUEL INJECTOR**

(57) The present invention provides a fuel injector (1) for use in an internal combustion engine, the fuel injector (1) comprising: a nozzle body (30) having a bore (31) for receiving fuel; a valve needle (20); and a lift stop component (50); wherein the valve needle (20) is slidable within the bore (31) between a closed position in which the valve needle (20) engages a nozzle seat (32) provided by the nozzle body (30) and a position of maximum lift in which the valve needle (20) engages the lift stop component (50); wherein the fuel injector (1) further comprises an engagement element (26) provided on the valve needle (20) at an end of the valve needle closest to the lift stop component (50), wherein the valve needle (20) is arranged to engage the lift stop component (50) via the engagement element (26) when in its position of maximum lift. The present invention also provides a method of manufacturing a fuel injector (1).

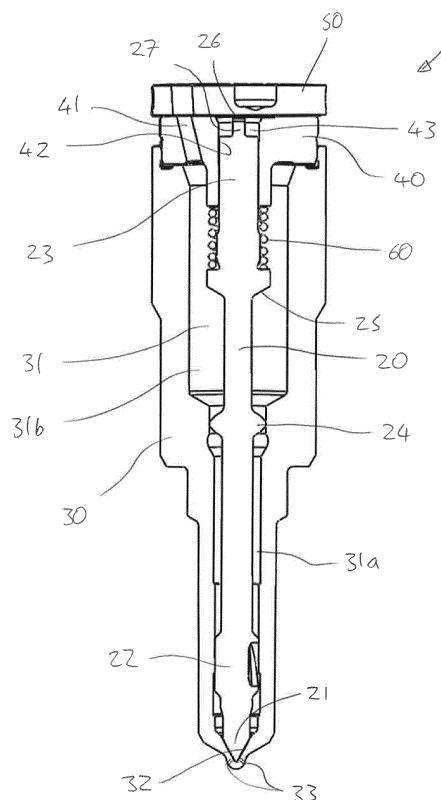


Figure 1

Description

TECHNICAL FIELD

[0001] The present invention relates to a fuel injector for use in an internal combustion engine, and to a method of manufacturing a fuel injector for use in an internal combustion engine.

BACKGROUND

[0002] Fuel injectors for internal combustion engines generally comprise a nozzle body having a bore for receiving fuel and a valve needle that is slidable within the bore. The valve needle is slidable between a closed position in which a tip of the valve needle engages a nozzle seat provided by the nozzle body and a position of maximum lift in which a proximal end of the valve needle engages a lift stop component. When the valve needle is in its closed position it acts to prevent fuel from being delivered from the bore, but when the valve needle is displaced from its closed position towards its position of maximum lift fuel may be dispensed from the bore via one or more outlets provided in the nozzle body.

[0003] In some cases it may be desirable to monitor the position of the valve needle of a fuel injector during use of the fuel injector so that the performance of the fuel injector can be analysed and/or controlled. In some fuel injectors it is possible to determine when the valve needle is in its closed position or in its position of maximum lift by using the valve needle as an electrical switch that completes an electrical circuit when in contact with the nozzle seat (in its closed position) or the lift stop component (in its position of maximum lift). However, this measurement system does not allow the difference between the closed position and the position of maximum lift to be detected. In addition, modifying an existing design of fuel injector to include a measurement system of this type may require the addition of further components, such as resistive washers or spacers, which may increase the distance between the nozzle body and the lift stop component, and therefore affect the performance of the fuel injector.

[0004] Another problem with known fuel injectors is that components need to be manufactured using very tight tolerances in order to ensure reliable and predictable operation of the fuel injector, which makes manufacturing fuel injector components difficult, time-consuming and expensive. If a fuel injector component deviates in dimensions or geometry from its intended design then it may be necessary to discard the component if the deviation falls outside manufacturing tolerances. Even if the deviation falls within manufacturing tolerances, the deviation may still affect the performance of a fuel injector in which the component is incorporated. For example, a manufacturing variation in the length of a valve needle may affect the distance over which the valve needle is slidable between its closed position and its position of

maximum lift, and the distance between the tip of the valve needle and the nozzle seat when the valve needle is in its position of maximum lift.

[0005] It is an object of the present invention to provide a fuel injector which addresses the shortcomings of the prior art.

SUMMARY OF THE INVENTION

[0006] A first aspect of the invention provides a fuel injector for use in an internal combustion engine, the fuel injector comprising a nozzle body having a bore for receiving fuel; a valve needle; and a lift stop component. The valve needle is slidable within the bore between a closed position in which the valve needle engages a nozzle seat provided by the nozzle body and a position of maximum lift in which the valve needle engages the lift stop component. The fuel injector further comprises an engagement element provided on the valve needle at an end of the valve needle closest to the lift stop component, wherein the valve needle is arranged to engage the lift stop component via the engagement element when in its position of maximum lift.

[0007] The engagement element may provide several different advantages. For example, the engagement element may act as a height adjustment device allowing the location of the valve needle relative to the nozzle body when in its position of maximum lift to be set during manufacture of the fuel injector. Alternatively, or in addition, the engagement element may act as an electrically resistive layer forming part of an electrical pathway between the valve needle and the lift stop component when the valve needle is in its position of maximum lift, which may allow improved monitoring of the position of the valve needle during use of the fuel injector.

[0008] The engagement element may comprise a separately formed component that has been attached to the valve needle. The separate component may be substantially planar, and may take the form, for example, of a substantially planar disk. Other shapes are also possible.

[0009] The engagement element may be attached to the valve needle by an adhesive or by a welded connection or by a press-fit connection.

[0010] The engagement element may be partially received in a recess formed in the end of the valve needle closest to the lift stop component. Alternatively the engagement element may be located directly on an end face of the valve needle without being received in any recess, or may be located on (and may at least partially surround) a protrusion extending from a proximal end of the valve needle.

[0011] The engagement element may comprise a coating that has been formed on the valve needle at its end closest to the lift stop device. The coating may be provided only on an end surface of the valve needle facing towards the lift stop component, and need not extend along a length of the valve needle.

[0012] The lift stop component may be located at an

intermediate position between the valve needle and a control valve for controlling fuel pressure in a control chamber located below the lift stop component, and/or between the valve needle and an actuation mechanism for controlling a control valve. The lift stop component may be a control valve housing, in which case at least a portion of the control valve may be located within the lift stop component. The lift stop component may comprise a passage allowing fluid communication between the control valve and the control chamber.

[0013] The engagement element may be a height adjustment device having a height in a direction parallel to a direction of movement of the valve needle that is selected so as to set the location of the valve needle relative to the nozzle body when in its position of maximum lift. The height adjustment device may allow the location of the valve needle relative to the nozzle body when in its position of maximum lift to be set during manufacture of the fuel injector, for example to compensate for an increase in the distance between the nozzle body and the lift stop component caused by the addition of one or more further components of the fuel injector, and/or to compensate for manufacturing variations of one or more components of the fuel injector.

[0014] The height of the height adjustment device may be in the range 0.1 mm to 3mm, or in the range 0.3mm to 2mm, or in the range 0.5mm to 1.5mm, although other heights are also possible, depending on the specific application.

[0015] The height adjustment device may be formed of the same material as the valve needle. However, other materials are also possible. The height adjustment device may, for example, be formed of high speed or high strength steel, a carbide-containing metal alloy, or a ceramic material.

[0016] The engagement element may be an electrically resistive layer forming part of the electrical pathway formed between the valve needle and the lift stop component when the valve needle is in its position of maximum lift. The electrically resistive layer acts to increase the electrical resistance between the valve needle and the lift stop component when the valve needle is in its position of maximum lift. The electrically resistive layer may therefore act to set the voltage of the valve needle and/or the current flowing through the valve needle when the valve needle is in its position of maximum lift. By setting the voltage of the valve needle and/or the current flowing through the valve needle when the valve needle is in its position of maximum lift the electrically resistive layer may allow the position of the valve needle to be determined more accurately.

[0017] The electrically resistive layer may provide a resistance of 10 Ohms to 40 kOhms, or 500 Ohms to 20 kOhms.

[0018] The electrically resistive layer may be formed of (or comprise a coating formed of) a material having a resistivity of at least $0.003 (3 \times 10^{-3})$ Ohm.m.

[0019] The electrically resistive layer may be formed

of (or comprise a coating formed of), for example, a ceramic material (which may include a dopant or doping agent) or aluminium oxide.

[0020] The electrically resistive layer may have a height in a direction parallel to a direction of movement of the valve needle of 0.1 to 3mm, or 0.3 to 2mm, or 0.5 to 1.5mm, although other heights are also possible, depending on the specific application and the material(s) used for the electrically resistive layer.

[0021] The fuel injector may further comprises a measurement system comprising an electrically conductive pathway arranged to be connected to a power supply in order to apply a voltage to the valve needle, wherein the electrically resistive layer acts to increase the electrical resistance between the valve needle and the lift stop component when the valve needle is in its position of maximum lift to thereby set the voltage of the valve needle and/or the current flowing through the valve needle when the valve needle is in its position of maximum lift. The electrically resistive layer may therefore act to set the voltage of the valve needle and/or the current flowing through the valve needle when the valve needle is in its position of maximum lift.

[0022] The electrically conductive pathway may comprise a conductive element that is arranged to be coupled to an external power supply. The conductive element may be electrically coupled to the valve needle via a conductive piston guide provided between the valve nozzle and the lift stop component. In use, the measurement system may be electrically coupled to a control system that is arranged to measure the voltage on the valve needle and/or the current flowing through the valve needle, and to determine the position of the valve needle in dependence on the measured voltage and/or current.

[0023] The electrically resistive layer may cause the voltage of the valve needle and/or the current flowing through the valve needle when the valve needle is in its position of maximum lift to be different to the voltage of the valve needle and/or the current flowing through the valve needle when the valve needle is in its closed position. It will be appreciated that even without the electrically resistive layer the voltage on the valve needle and/or the current flowing through the valve needle may be slightly different for the closed position and the position of maximum lift. However, the electrically resistive layer acts to increase the difference between the voltage on the valve needle and/or the current flowing through the valve needle for the closed position and the position of maximum lift, thereby allowing a difference between the closed position and the position of maximum lift to be more easily detected.

[0024] The electrically resistive layer may cause the voltage of the valve needle to be higher when the valve needle is in its position of maximum lift than when the valve needle is in its closed position and/or may cause the current flowing through the valve needle to be lower when the valve needle is in its position of maximum lift than when the valve needle is in its closed position.

[0025] A second aspect of the present invention provides a method of manufacturing a fuel injector for use in an internal combustion engine, the method comprising providing a nozzle body having a bore for receiving fuel, a valve needle and a lift stop component; providing a height adjustment device on the end of the valve needle that is arranged to be closest to the lift stop component; and assembling the nozzle body, the valve needle and the lift stop component together. The height of the height adjustment device is selected so as to set the location of the valve needle relative to the nozzle body when in its position of maximum lift.

[0026] The height adjustment device may be used to ensure that the valve needle is in the desired location relative to the nozzle body when in its position of maximum lift in several different ways, as described below.

[0027] The step of providing the height adjustment device may comprise providing a separately formed height adjustment device and attaching the height adjustment device to the valve needle; or alternatively the step of providing the height adjustment device may comprise forming a height adjustment coating on the valve needle.

[0028] The step of providing the height adjustment device may comprise arranging a plurality of height adjustment elements together to form a height adjustment device of the desired height.

[0029] The step of providing the height adjustment device may comprises grinding the height adjustment device to modify the height of the height adjustment device. Grinding may occur either before or after the height adjustment device has been attached to or formed on the valve needle.

[0030] The height of the height adjustment device may be selected to compensate for an increase in the distance between the nozzle body and the lift stop component caused by the addition of one or more further components of the fuel injector. The further component(s) may, for example, be one or more washers or spacers. The further component(s) may be located on one or both sides of a piston guide provided between the nozzle body and the lift stop component. The height of the height adjustment device may be selected in dependence on the height of the further component(s) and/or in dependence on the increase in the distance between the nozzle body and the lift stop component caused by the addition of the further component(s).

[0031] In this way it may be possible to retain the same design of nozzle body and valve needle (with the addition of the height adjustment device) when a pre-existing design of a fuel injector is modified to include one or more further components that act to increase the distance between the nozzle body and the lift stop component. The compensation provided by the height adjustment device may enable the location of the valve needle relative to the nozzle body when in its position of maximum lift to remain as originally intended despite the increase in the distance between the nozzle body and the lift stop component caused by the addition of the further compo-

nent(s).

[0032] Alternatively, or in addition, the height of the height adjustment device may be selected to compensate for manufacturing variations of one or more components of the fuel injector. The height of the height adjustment device may be selected to compensate for any manufacturing variations that will affect the distance between the nozzle body and the lift stop component and/or the distance between a tip of the valve needle and a nozzle seat of the nozzle body when the valve needle is in its position of maximum lift and/or the distance over which the valve needle is slidable within the bore of the nozzle body once the fuel injector has been assembled. For example, the height of the height adjustment device may be selected to compensate for manufacturing variations in one or more of: valve needle length, valve needle tip geometry, nozzle body length, nozzle seat location, nozzle seat geometry, lift stop component geometry, and the height of any component (such as a piston guide or washer) that may be provided between the nozzle body and the lift stop component.

[0033] The height of the height adjustment device may be selected in dependence on one or more measurements of the dimensions and/or geometry of any component that will affect the distance between the nozzle body and the lift stop component and/or the distance between a tip of the valve needle and a nozzle seat of the nozzle body when the valve needle is in its position of maximum lift and/or the distance over which the valve needle is slidable within the bore of the nozzle body once the fuel injector has been assembled. For example, the method may include a step of measuring the length of the valve needle and/or measuring the length of the nozzle body, and a step of selecting the height of the height adjustment device in dependence on the measured length(s) of the valve needle and/or the nozzle body.

[0034] In this way the height adjustment device may be used to compensate for manufacturing variations of one or more components of the fuel injector to thereby prevent or minimise deviations in the intended location of the valve needle relative to the nozzle body and/or the nozzle seat when in its position of maximum lift that might otherwise be caused by manufacturing variations of various fuel injector components.

[0035] Alternatively, or in addition, the height of the height adjustment device may be selected to tune the distance between a tip of the valve needle and a nozzle seat of the nozzle body when the valve needle is in its position of maximum lift in order to achieve a desired operating characteristic for the fuel injector. For example, a greater height for the height adjustment device may be selected in order to reduce the distance between the tip of the valve needle and the nozzle seat, or a smaller height for the height adjustment device may be selected in order to increase the distance between the tip of the valve needle and the nozzle seat. In this way, the operating characteristics of a fuel injector (such as the flow rate profile and the opening and closing times) may be

tuned as desired without varying the dimensions or designs of other components of the fuel injector. It is therefore possible to produce fuel injectors with different operating characteristics using the same components simply by selecting an appropriate height for the height adjusters of the respective fuel injectors.

[0036] The method of the second aspect of the invention may be used in manufacturing a fuel injector according to the first aspect of the invention (where the engagement element is a height adjustment device). The method of the second aspect of the invention may include any steps associated with manufacturing a fuel injector according to the first aspect of the invention (where the engagement element is a height adjustment device). The fuel injector of the first aspect of the invention (where the engagement element is a height adjustment device) may include any features resulting from steps described in relation to the second aspect of the invention.

[0037] 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. That is, all embodiments and/or features of any aspect or embodiment can be combined in any way and/or combination with those in other aspects and/or embodiments, unless such features are incompatible.

BRIEF DESCRIPTION OF THE DRAWINGS

[0038] In order that the present invention may be more readily understood, exemplary embodiments of the invention will now be described in detail with reference to the accompanying figures, in which:

Figure 1 illustrates a fuel injector according to one possible embodiment of the present invention;
 Figure 2 illustrates an enlarged detail of a portion of the fuel injector of Figure 1;
 Figure 3 illustrates voltage measurements obtained from a measurement system for determining the position of a valve needle of a fuel injector according to one possible embodiment of the invention;
 Figure 4 illustrates voltage measurements obtained from a measurement system for determining the position of a valve needle of a fuel injector according to another possible embodiment of the invention; and
 Figures 5 to 7 illustrate alternative arrangements of engagement elements according to other possible embodiments of the present invention.

DETAILED DESCRIPTION

[0039] For the purpose of the following description it will be appreciated that references to upper, lower, upward, downward, above and below, for example, are not intended to be limiting and relate only to the orientation

of the injector as shown in the illustration.

[0040] The present invention relates generally to a fuel injector 1 of the type illustrated (in part) in Figure 1. The fuel injector 1 is suitable for use in a fuel injection system of an internal combustion engine, and particularly a diesel engine in which fuel is typically injected into the engine at high pressure levels in excess of 2000 bar, and commonly as high as 3000 bar.

[0041] The fuel injector 1 comprises a valve needle 20 that is slidable within a bore 31 of a nozzle body 30. A proximal end of the nozzle body 30 is coupled to a piston guide 40, which in turn sits below a lift stop component 50. An upper insulating washer 45 is provided between the piston guide 40 and the lift stop component 50 to electrically isolate the piston guide 40 from the lift stop component 50, and a lower insulating washer 46 is provided between the piston guide 40 and the nozzle body 30 to electrically isolate the piston guide 40 from the nozzle body 30. The proximal end of the bore 31 receives high pressure fuel, in use, from a supply line 41 provided in the piston guide 40. The bore 31 includes a section of comparatively small diameter 31 a towards its distal end and a section of comparatively large diameter 31 b towards its proximal end.

[0042] The bore 31, at its distal end, defines a nozzle seat 32 of generally frusto-conical form with which a tip 21 of the valve needle 20 is engageable. At or downstream of the nozzle seat 32, the nozzle body 30 is provided with a plurality of outlets 33 for delivering fuel to a combustion cylinder, in use. When the valve needle 20 is in its closed position, the tip 21 of the valve needle is engaged with the nozzle seat 32 to prevent fuel from being delivered from the bore 31 through the outlets 33. However, when the valve needle 20 is lifted away from the nozzle seat 32 and towards the lift stop component 50 during operation of the fuel injector 1, the tip 21 of the valve needle 20 moves out of engagement with the nozzle seat 32 to allow fuel to be delivered from the bore 31 through the outlets 33. The valve needle 20 is arranged to engage the lift stop component 50 when in its position of maximum lift (at the top of its travel) such that the lift stop component prevents further movement of the valve needle 20 away from the nozzle seat 32. A spring 60 is provided towards a proximal end of the valve needle 20, which acts to urge the valve needle 20 towards its closed position.

[0043] The valve needle 20 comprises a valve needle guide 22 towards its distal end. The valve needle guide 22 slidably engages the bore 31 in the section of comparatively small diameter 31 a to prevent lateral movement of the valve needle 20 within the bore. The valve needle guide 22 includes a plurality of grooves to permit the passage of fuel past the valve needle guide. The valve needle 20 also comprises a proximal guide portion 23 at its proximal end that slidably engages a bore 42 of the piston guide 40 to prevent lateral movement of the valve needle 20 within the bore 31 of the nozzle body 30. The valve needle 20 also comprises a restrictive element 24

at an intermediate location between the valve needle guide 22 and the proximal guide portion 23 for restricting the flow of fuel through the bore 31 past the restrictive element 24. The restrictive element 24 may comprise a plurality of grooves or orifices to permit the passage of fuel past the restrictive element, and may optionally act as an intermediate valve needle guide by slidably engaging the bore 31.

[0044] The valve needle 20 is provided with a plurality of thrust surfaces that are exposed to fuel pressure within the bore 31 to impart upward and downward forces on the valve needle. For example, the valve needle 20 is provided with a primary thrust surface 25 that faces downwardly (when the fuel injector is arranged as shown in Figure 1) in order to impart an upward force to the valve needle to urge the valve needle away from its closed position. The valve needle also includes other downwardly facing thrust surfaces that act to impart upward forces to the valve needle to urge the valve needle away from its closed position, and upwardly facing thrust surfaces that act to impart downward forces to the valve needle to urge the valve needle towards its closed position.

[0045] The valve needle 20 is provided with an engagement element 26 at its proximal end (closest to the lift stop component 50), as shown more clearly in the enlarged view of Figure 2. The valve needle 20 is arranged to engage the lift stop component 50 via the engagement element 26 when in its position of maximum lift. The engagement element 26 takes the form of a separately formed component that is attached to the proximal end of the valve needle 20, for example, by a welded connection or by an adhesive. In the embodiment illustrated in Figure 1 the engagement element 26 is shaped as a planar disk, and is provided on a protrusion 27 extending from the proximal end of the valve needle 20. The engagement element may be formed of the same material as the main body of the valve needle 20, although other materials are also possible, as described below.

[0046] A control chamber 43 is provided within the piston guide 40 between a lower surface of the lift stop component 50 and the proximal end of the valve needle 20 (that is the end closest to the lift stop component 50 and furthest from the nozzle seat 32). Movement of the valve needle 20 is controlled by varying the fuel pressure in the control chamber 43 and thus the downward force exerted on the valve needle by the fuel within the control chamber 43. The operating cycle of the fuel injector will be well understood by those skilled in the art.

[0047] Fuel pressure within the control chamber 43 may be controlled, for example, by operating a three-way control valve using a piezo-electric or solenoid type actuator. The three-way control valve may be operated to supply high pressure fuel to the control chamber 43 without any connection to a low pressure drain (in order to generate a high pressure within the control chamber 43), and to connect the control chamber to the low pressure drain (in order to reduce the pressure within the control chamber 43). The control valve may be located at least

partially within the lift stop component, which may act as a control valve housing. The lift stop component may comprise a passage allowing fluid communication between the control valve and the control chamber. Other actuation systems are also possible.

[0048] The fuel injector 1 further comprises a measurement system for enabling the position of the valve needle to be determined during operation of the fuel injector 1. The measurement system comprises an electrically conductive pathway arranged to be connected to an external power supply in order to apply a voltage to the valve needle. The electrically conductive pathway comprises a wire 70 (illustrated in Figure 2) having a proximal end that is arranged to be connected to the external power supply via a connector that is fitted to the fuel injector 1 in use. The wire 70 is electrically connected at its distal end to the piston guide 40. An electrical connection is established between the wire 70 and the valve needle 20 via the piston guide 40. The upper and lower insulating washers 45, 46 act to insulate the piston guide 40 from the lift stop component 50 and the nozzle body 30, as described above. In use, the wire 70 of the measurement system is electrically coupled to a control system which is arranged to measure the voltage on the valve needle 20 and/or the current flowing through the valve needle 20 to thereby determine the position of the valve needle 20. The control system may be integrated with the power supply.

[0049] Operation of the measurement system to determine the position of the valve needle 20 will now be described.

[0050] During use of the fuel injector, the external power supply applies a voltage to the valve needle 20 via the wire 70 and the piston guide 40, for example at 5V. The voltage on the valve needle and the current flowing through the valve needle vary during operation of the fuel injector according to the position of the valve needle. For example, when the valve needle 20 is at an intermediate position between its closed position and its open position it is not electrically connected to the lift stop component 50. In addition, due to electrically resistive coatings provided on one or both of the valve needle and the nozzle body at the locations of the valve needle guide 22 and the restrictive element 24, the valve needle is also not electrically connected to the nozzle body 30. Therefore the voltage on the valve needle is approximately 5V, and substantially no current flows through the valve needle.

[0051] However, when the valve needle 20 is in its closed position, the valve needle is then electrically connected to the nozzle body 30 due to the engagement between the tip 21 of the valve needle 20 and the nozzle seat 32 of the nozzle body 30. Therefore the voltage on the valve needle drops and the current flowing through the valve needle increases. Similarly, when the valve needle 20 is in its position of maximum lift, the valve needle is then electrically connected to the lift stop component 50 due to the engagement between the engagement element 26 provided on the proximal end of the valve

needle 20 and the lower surface of the lift stop component 50. Therefore the voltage on the valve needle drops (compared to the intermediate position) and the current flowing through the valve needle increases (compared to the intermediate position).

[0052] By monitoring the voltage on the valve needle 20 and/or the current flowing through the valve needle, the control system is able to determine whether the valve needle is in an intermediate position or in either its closed position or its position of maximum lift.

[0053] The presence of the upper and lower insulating washers 45, 46 in the fuel injector 1 result in an increase in the distance between the nozzle body 30 and the lift stop component 50 compared to a similar fuel injector in which the upper and lower insulating washers 45, 46 are not present. This would tend to lead to an increase in the distance between the tip 21 of the valve needle 20 and the nozzle seat 32 of the nozzle body 30 when the valve needle is in its position of maximum lift, and an increase in the total distance over which the valve needle 20 is slidable within the bore compared to a similar fuel injector in which the upper and lower insulating washers 45, 46 are not present. However, by adding the engagement element 26 at the proximal end of the valve needle 20, it is possible to compensate for these changes by increasing the effective length of the valve needle 20.

[0054] In the present embodiment the height H of the engagement element 26 in a direction parallel to the direction of movement M of the valve needle 20 is selected in dependence on the increase in the distance between the nozzle body 30 and the lift stop component 50 to thereby reduce or eliminate any potential change in the distance between the tip 21 of the valve needle 20 and the nozzle seat 32 of the nozzle body 30 when the valve needle is in its position of maximum lift (and distance over which the valve needle is slidable within the bore) compared to a similar fuel injector in which the upper and lower insulating washers 45, 46 are not present. For example, if the upper and lower insulating washers 45, 46 together result in an increase of 0.5mm (or alternatively 0.1 mm) to the distance between the nozzle body 30 and the lift stop component 50 then the height H of the engagement element may be set as 0.5mm (or alternatively 0.1 mm) to compensate for this increase.

[0055] In this way the engagement element 26 acts as a height adjustment device that sets the location of the valve needle 20 relative to the nozzle body 30 when in its position of maximum lift by compensating for an increase in the distance between the nozzle body 30 and the lift stop component 50 caused by the addition of the upper and lower insulating washers 45, 46. It is therefore possible to modify an existing fuel injector design to include the upper and lower insulating washers 45, 46 without changing the design of the nozzle body 30 or valve needle 20 and without changing the location of the valve needle 20 relative to the nozzle body 30 when in its position of maximum lift.

[0056] In the present embodiment the engagement el-

ement 26 acts as a height adjustment device that sets the location of the valve needle 20 relative to the nozzle body 30 when in its position of maximum lift by compensating for an increase in the distance between the nozzle body 30 and the lift stop component 50 caused by the addition of one or more further components. In this case, the height H of the engagement element 26 may be pre-determined based on a known height of the further components and/or a known increase in the distance between the nozzle body and the lift stop component caused by the addition of the further components. Therefore the selection of the height H of the engagement element 26 may occur when the design of the fuel injector is conceived (or modified to include the further components), and each fuel injector 1 manufactured to that design may include an engagement element 26 having the same height H. In this case engagement elements 26 of a standard, uniform height may be used in manufacturing a plurality of the fuel injectors 1.

[0057] In another embodiment, alternatively or in addition to compensating for an increase in the distance between the nozzle body 30 and the lift stop component 50 caused by the addition of one or more further components 45, 46, the engagement element 26 may be arranged to set the location of the valve needle 20 relative to the nozzle body 30 when in its position of maximum lift by compensating for manufacturing variations of one or more components of the fuel injector 1.

[0058] In this case, during manufacture of the fuel injector 1, the height H of the engagement element 26 may be selected in dependence on one or more measurements of the dimensions and/or geometry of one or more components that may affect the distance between the nozzle body 30 and the lift stop component 50 and/or the distance between a tip 21 of the valve needle 20 and a nozzle seat 32 of the nozzle body 30 when the valve needle is in its position of maximum lift and/or the distance over which the valve needle 20 is slidable within the bore 31 of the nozzle body 30 once the fuel injector 1 has been assembled.

[0059] For example, the process of manufacturing the fuel injector 1 may include a step of measuring the length of the valve needle 20, and a step of selecting the height H of the engagement element 26 in dependence on the measured length of the valve needle 20. In this example, the height H of the engagement element 26 may be selected to be lower than a standard reference height to compensate for a valve needle 20 that is slightly longer than intended due to a manufacturing variation, or selected to be greater than the standard reference height to compensate for a valve needle 20 that is slightly shorter than intended due to a manufacturing variation.

[0060] The selection of the height H of the engagement element 26 may take into account manufacturing variations for several different components, for example the length of the nozzle body 30. In this case a greater height H of engagement element 26 may be used to compensate for a nozzle body 30 that is slightly longer than in-

tended due to a manufacturing variation, or a lower height H of engagement element 26 may be used to compensate for a nozzle body 30 that is slightly shorter than intended due to a manufacturing variation.

[0061] Other manufacturing variations may also be accounted for, including, for example, valve needle tip geometry, nozzle seat location, nozzle seat geometry, lift stop component geometry, and insulating washer height. The height of the engagement element may be selected in dependence on the net effect of multiple different manufacturing variations of different components.

[0062] Where the engagement element 26 acts as a height adjustment device to compensate for manufacturing variations of other components, different fuel injectors 1 manufactured to the same design may include engagement elements 26 of different heights H in order to compensate for different manufacturing variations.

[0063] The required height H of engagement element 26 may be obtained, for example, by selecting an engagement element 26 of the required height from a plurality of engagement elements having different heights. Alternatively (or in addition) the required height H may be obtained by arranging a plurality of height adjustment elements together in the height direction to form an engagement element 26 of the required height and/or grinding the engagement element 26 to achieve the required height.

[0064] In this way the engagement element 26 may act as a height adjustment device that sets the location of the valve needle 20 relative to the nozzle body 30 when in its position of maximum lift by compensating for manufacturing variations of one or more components of the fuel injector. It is therefore possible to prevent or minimise deviations in the intended location of the valve needle 20 relative to the nozzle body 30 and/or the nozzle seat 32 when in its position of maximum lift that might otherwise be caused by manufacturing variations of various fuel injector components.

[0065] In another embodiment, alternatively or in addition to compensating for an increase in the distance between the nozzle body 30 and the lift stop component 50 caused by the addition of one or more further components 45, 46 and/or compensating for manufacturing variations of one or more components of the fuel injector 1, the engagement element 26 may be used as a height adjustment device to tune the distance between the tip 21 of the valve needle 20 and the nozzle seat 32 when the valve needle is in its position of maximum lift, in order to achieve a desired operating characteristic for the fuel injector 1.

[0066] The operating characteristics of the fuel injector 1 (such as the flow rate profile and the opening and closing times) are affected by the distance between the tip 21 of the valve needle 20 and the nozzle seat 32 when the valve needle is in its position of maximum lift. For example, a smaller distance between the tip 21 of the valve needle 20 and the nozzle seat 32 will generally lead to a reduced flow rate and quicker opening and closing

times, while a greater distance between the tip 21 of the valve needle 20 and the nozzle seat 32 will generally lead to an increased flow rate and slower opening and closing times. Since the height H of the engagement element 26 affects the distance between the tip 21 of the valve needle 20 and the nozzle seat 32 when the valve needle is in its position of maximum lift, it is possible to tune this distance (and therefore the operating characteristics of the fuel injector 1) by selecting an appropriate height for the engagement element. It is therefore possible to produce fuel injectors 1 with different operating characteristics using the same components simply by selecting an appropriate height H for the engagement elements 26 of the respective fuel injectors, for example to produce a lower flow rate fuel injector 1 (using an engagement element 26 with a greater height) and a comparatively higher rate fuel injector 1 (using an engagement element 26 with a smaller height).

[0067] The engagement elements 26 used for tuning the distance between the tip 21 of the valve needle 20 and the nozzle seat 32 may be selected from discrete groups with pre-determined heights, for example a first height corresponding to a first desired operating characteristic (such as a lower flow rate) and a second height corresponding to a second desired operating characteristic (such as a higher flow rate). Alternatively, the height may be set at any desired level to achieve any intermediate operating characteristic.

[0068] It will be appreciated that the same engagement element 26 may be used as a height adjustment device for any combination of a) compensating for an increase in the distance between the nozzle body 30 and the lift stop component 50 caused by the addition of one or more further components 45, 46, b) compensating for manufacturing variations of one or more components of the fuel injector 1, and c) tuning the distance between the tip 21 of the valve needle 20 and the nozzle seat 32 when the valve needle is in its position of maximum lift in order to achieve a desired operating characteristic for the fuel injector 1.

[0069] In another embodiment, alternatively or in addition to acting as a height adjustment device, the engagement element 26 may be arranged to act as an electrically resistive layer. The electrically resistive layer may, for example, provide a resistance of 500 Ohms, although other resistances are also possible. The engagement element 26 may be arranged to act as an electrically resistive layer either by forming the engagement element 26 of a material having a sufficiently high resistivity (for example a ceramic material including a dopant or doping agent) or by providing the engagement element with an electrically resistive coating (for example a coating formed of aluminium oxide). It will be appreciated that the resistance provided by the engagement element 26 is dependent both upon its height and its resistivity (or upon the properties of any resistive coating) and that various different heights and materials (or coatings) may be employed in order to enable the engagement element to

act as an electrically resistive layer.

[0070] As described above, the engagement element 26 forms part of the electrical pathway between the valve needle 20 and the lift stop component 50 when the valve needle 20 is in its position of maximum lift. By arranging the engagement element 26 to act as an electrically resistive layer, the engagement element 26 may act to increase the electrical resistance between the valve needle 20 and the lift stop component 50 when the valve needle 20 is in its position of maximum lift. In this way, the engagement element 26 may set the voltage on the valve needle 20 and the current flowing through the valve needle when the valve needle is in its position of maximum lift.

[0071] For example, an engagement element 26 that is arranged to act as an electrically resistive layer used in combination with a measurement system as described above will tend to increase the voltage on the valve needle 20 and reduce the current flowing through the valve needle when the valve needle is in its position of maximum lift. The engagement element 26 will therefore cause a different voltage and/or current reading to be obtained for the position of maximum lift compared to the closed position (or at least increase the difference in voltage and/or current readings for these two positions). It is therefore possible (or at least easier) to determine whether the valve needle 20 is in its closed position or its position of maximum lift due to the different voltage and/or current readings for these two positions. By differentiating between the closed position and the position of maximum lift the engagement element 26 may allow more accurate analysis of the performance of the fuel injector 1, especially during phases of operation in which the valve needle 20 does not reach its position of maximum lift in between closed periods. The difference between the voltage readings for the closed position and the position of maximum lift is illustrated in Figure 3.

[0072] For comparison, Figure 4 illustrates the equivalent voltage readings for an alternative embodiment in which the engagement element acts as a height adjustment device but is not arranged to act as an electrically resistive layer (for example where the engagement element is formed of the same material as the main body of the valve needle), and in which identical voltage readings are returned for the closed position and the position of maximum lift.

[0073] Figure 5 illustrates an alternative embodiment in which the engagement element 26 is located directly on an end face of the valve needle 20 (instead of being provided on a protrusion extending from the proximal end of the valve needle).

[0074] Figure 6 illustrates an alternative embodiment in which the engagement element 26 is partially received in a recess formed in the proximal end of the valve needle 20.

[0075] Figure 7 illustrates another alternative embodiment in which the engagement element 26 is located on and partially surrounds the protrusion 27 provided on the proximal end of the valve needle 20.

[0076] In the embodiments shown in Figures 6 and 7 the engagement element 26 may be press fitted into or onto its corresponding feature on the valve needle 20 instead of being welded in place or attached by an adhesive.

[0077] In the above-described embodiments the engagement element 26 takes the form of a separately manufactured component that has been attached to the valve needle 20. However, in other embodiments, the engagement element (acting as a height adjustment device and/or as an electrically resistive layer) may alternatively take the form of a coating formed directly on the valve needle.

[0078] It will be appreciated that many further modifications and variations are also possible within the scope of the appended claims.

Claims

1. A fuel injector (1) for use in an internal combustion engine, the fuel injector comprising:
 - a nozzle body (30) having a bore (31) for receiving fuel;
 - a valve needle (20); and
 - a lift stop component (50);
 wherein the valve needle (20) is slidable within the bore (31) between a closed position in which the valve needle engages a nozzle seat (32) provided by the nozzle body (30) and a position of maximum lift in which the valve needle engages the lift stop component (50);
 wherein the fuel injector (1) further comprises an engagement element (26) provided on the valve needle (20) at an end of the valve needle closest to the lift stop component (50), wherein the valve needle is arranged to engage the lift stop component via the engagement element when in its position of maximum lift and,
 wherein the engagement element (26) comprises a separately formed component that has been attached to the valve needle (20) and,
 wherein the engagement element (26) is a height adjustment device having a height (H) in a direction parallel to a direction of movement (M) of the valve needle (20) that is selected so as to set the location of the valve needle relative to the nozzle body (30) when in its position of maximum lift and,
 wherein the height H of the height adjustment device (26) is in the range 0.1 to 3mm, or in the range 0.3 to 2mm, or in the range 0.4 to 1.5mm.
2. A fuel injector (1) according to claim 1, wherein the engagement element (26) is attached to the valve needle (20) by an adhesive or by a welded connection or by a press-fit connection.

3. A fuel injector (1) according to any of claims 1 or 2, wherein the engagement element (26) is an electrically resistive layer forming part of the electrical pathway formed between the valve needle (20) and the lift stop component (50) when the valve needle is in its position of maximum lift. 5
4. A fuel injector (1) according to claim 3, wherein the electrically resistive layer (26) provides a resistance of 10 Ohms to 40 kOhms, or 500 Ohms to 20 kOhms. 10
5. A fuel injector (1) according to claim 6 or claim 4, wherein the fuel injector further comprises a measurement system comprising an electrically conductive pathway (70) arranged to be connected to a power supply in order to apply a voltage to the valve needle (20), wherein the electrically resistive layer (26) acts to increase the electrical resistance between the valve needle and the lift stop component (50) when the valve needle is in its position of maximum lift. 15
6. A fuel injector (1) according to claim 5, wherein the electrically resistive layer (26) causes the voltage of the valve needle (20) and/or the current flowing through the valve needle when the valve needle is in its position of maximum lift to be different to the voltage of the valve needle and/or the current flowing through the valve needle when the valve needle is in its closed position. 20
7. A fuel injector (1) according to claim 6, wherein the electrically resistive layer (26) causes the voltage of the valve needle (20) to be higher when the valve needle is in its position of maximum lift than when the valve needle is in its closed position and/or wherein the electrically resistive layer causes the current flowing through the valve needle to be lower when the valve needle is in its position of maximum lift than when the valve needle is in its closed position. 25
8. A method of manufacturing a fuel injector (1) for use in an internal combustion engine, the method comprising: 30
 - providing a nozzle body (30) having a bore (31) for receiving fuel, a valve needle (20) and a lift stop component (50);
 - providing a height adjustment device (26) on the end of the valve needle (20) that is arranged to be closest to the lift stop component (50); and
 - assembling the nozzle body (30), the valve needle (20) and the lift stop component (50) together; 35
 - wherein the height (H) of the height adjustment device (26) is selected so as to set the location of the valve needle (20) relative to the nozzle body (30) when in its position of maximum lift. 40
9. A method according to claim 8, wherein the step of providing the height adjustment device (26) comprises providing a separately formed height adjustment device and attaching the height adjustment device to the valve needle (20); or alternatively wherein the step of providing the height adjustment device comprises forming a height adjustment coating on the valve needle. 45
10. A method according to claim 8 or 9, wherein the height (H) of the height adjustment device (26) is selected to compensate for an increase in the distance between the nozzle body (30) and the lift stop component (50) caused by the addition of one or more further components (45, 46) of the fuel injector (1). 50
11. A method according to any of claims 8 to 10, wherein the height (H) of the height adjustment device (26) is selected to compensate for manufacturing variations of one or more components of the fuel injector (1). 55
12. A method according to any of claims 8 to 11, wherein the height (H) of the height adjustment device (26) is selected to tune the distance between a tip (21) of the valve needle (20) and a nozzle seat (32) of the nozzle body (30) when the valve needle is in its position of maximum lift in order to achieve a desired operating characteristic for the fuel injector.

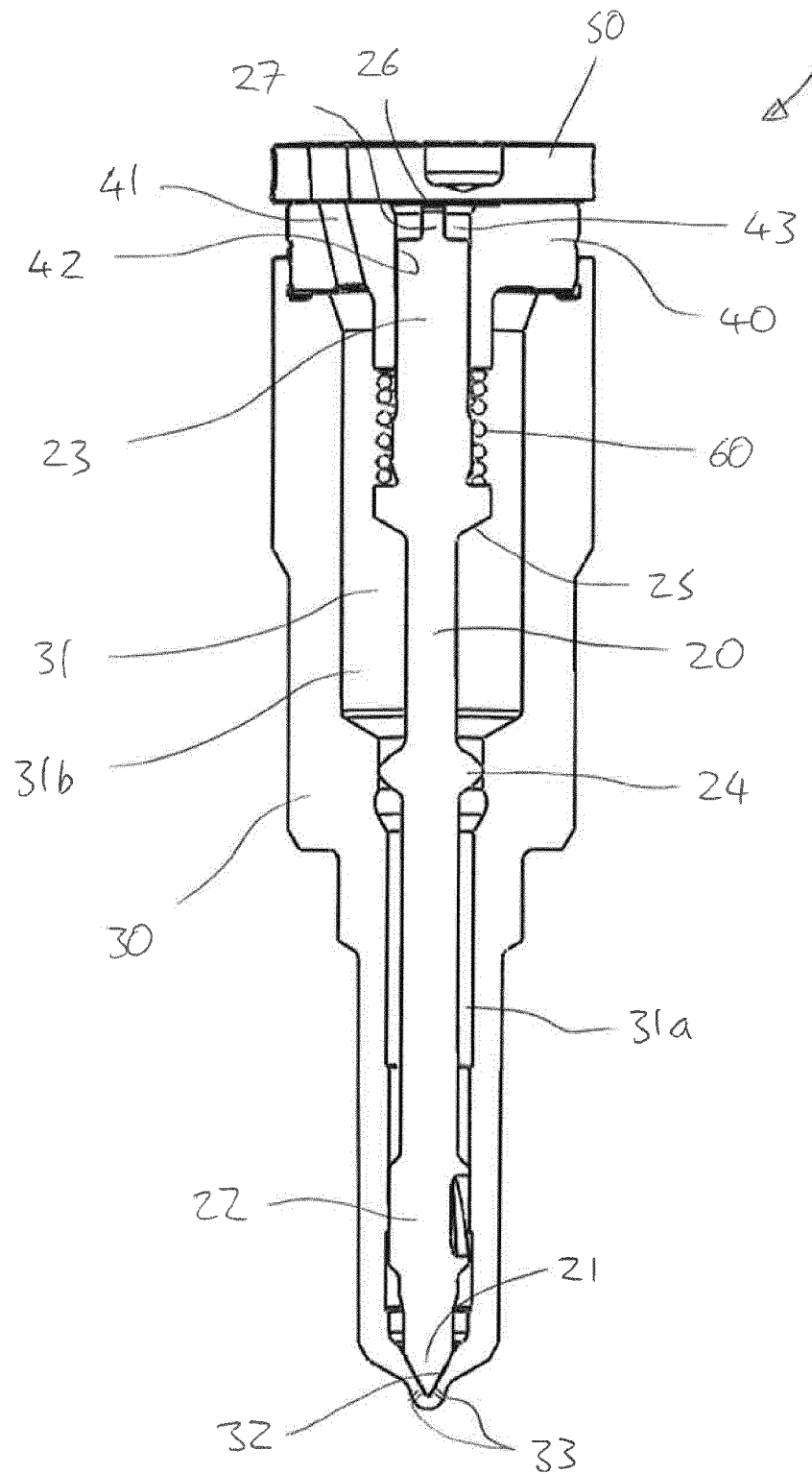
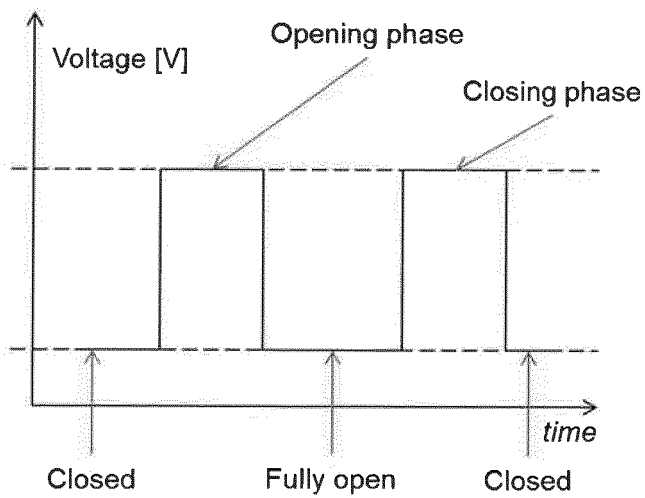
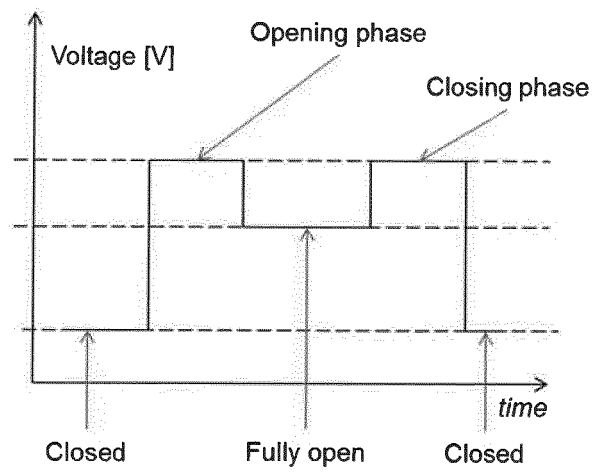
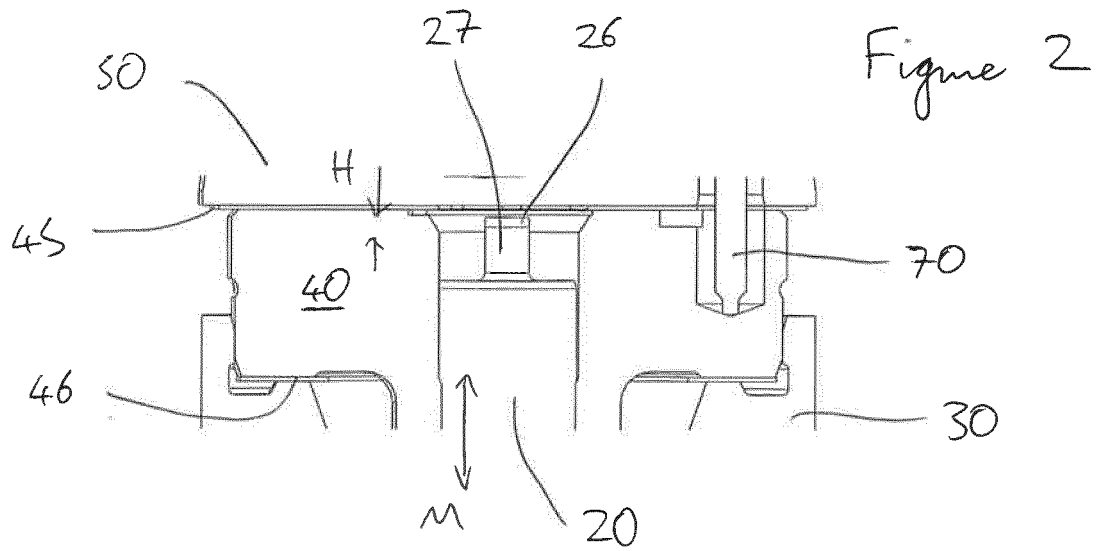


Figure 1



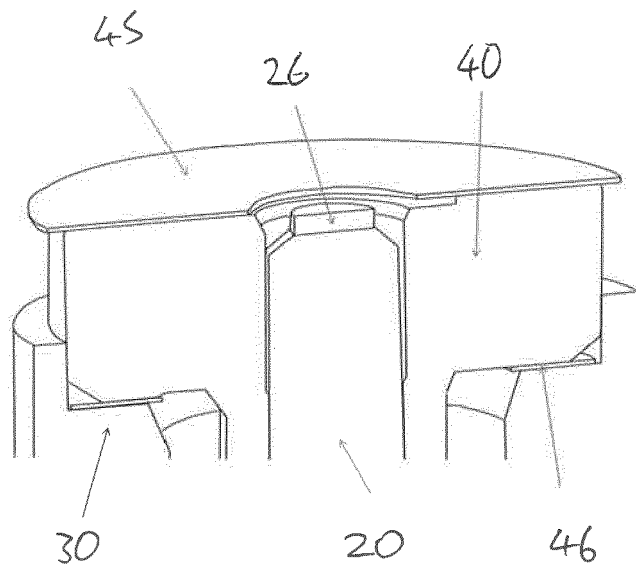


Figure 5

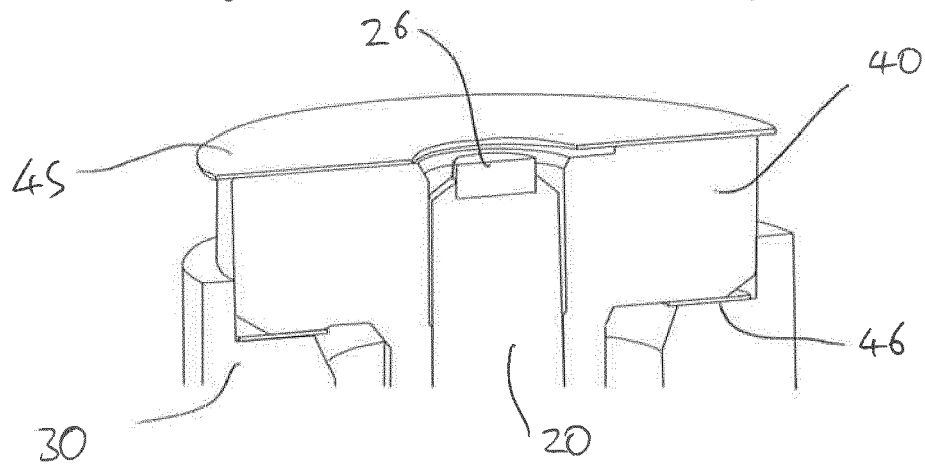


Figure 6

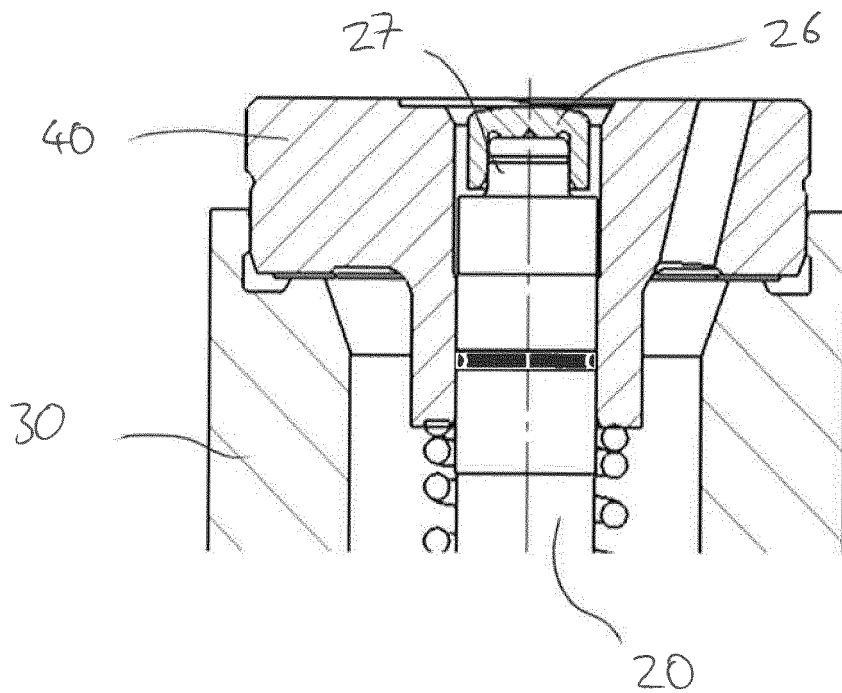


Figure 7



EUROPEAN SEARCH REPORT

Application Number
EP 17 16 2433

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			F02M
The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 31 August 2017	Examiner Hermens, Sjoerd
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			

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