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(54) **Fuel Injector**

Kraftstoffeinspritzdüse

Injecteur de carburant

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(73) Proprietor: **Delphi Technologies Holding S.à.r.l.**
4940 Bascharage (LU)

(72) Inventor: **Cooke, Michael**
Gillingham, Kent ME7 1DR (GB)

(74) Representative: **Gregory, John David Charles**
Delphi Diesel Systems
Patent Department
Courteney Road
Gillingham
Kent ME8 0RU (GB)

(56) References cited:
WO-A-02/095215
WO-A-03/040546
US-A1- 2003 116 657

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Description

TECHNICAL FIELD

[0001] This invention relates to a fuel injector for use in the delivery of fuel to a combustion space of an internal combustion engine. In particular, the invention relates to a fuel injector suitable for use in a so-called 'common rail' compression ignition combustion engine system.

BACKGROUND OF THE INVENTION

[0002] In an internal combustion engine, it is known for a fuel pump to supply fuel to a high-pressure accumulator (or common rail), from which it is delivered into each cylinder of the engine by means of a dedicated fuel injector. Typically, a fuel injector has an injection nozzle that is received within a bore provided in a cylinder head of the cylinder; and a valve needle which is actuated to control the release of high-pressure fuel into the cylinder from spray holes provided in the nozzle.

[0003] One simple way of opening and closing a valve needle is to couple a solenoid actuator directly to the valve needle, by attaching an armature of the actuator to the valve needle (or by providing a valve needle with an integral armature). The valve needle is biased towards a seating surface, so that, when the solenoid is not energised, the valve needle prevents fuel flow through the spray holes. When the solenoid is actuated, the valve needle is lifted away from its seating surface and a fuel injection takes place.

[0004] It has been recognised that, in order to cause initial movement of the valve needle away from its seating, a relatively large retracting force must be applied to the valve needle to overcome the downwards (closing) force on the valve needle. Once valve needle movement has been initiated and fuel is able to flow underneath the tip of the valve needle, a reduced force is sufficient to cause continued movement of the valve needle towards its full lift position. Curve N in Figure 1 shows, schematically, how the force required to move the needle varies as a function of the needle position (i.e. the magnitude of the needle lift above its fully-seated position).

[0005] In contrast, the force applied to the valve needle by the solenoid actuator upon energisation of the solenoid increases as the needle lifts, as shown by curve S in Figure 1. This is because the force acting on the armature is relatively low when the air gap between the armature and the solenoid is large, corresponding to the seated position of the valve needle, while the force acting on the armature increases as the air gap decreases.

[0006] Consequently, as is apparent from Figure 1, a solenoid actuator that is powerful enough to lift the valve needle initially is significantly over-specified for the remainder of the lifting movement, resulting in poor efficiency.

[0007] Furthermore, since the force available from a solenoid actuator is proportional to the area of the armature, an armature with a large area, and a correspondingly large volume and mass, must be provided in order to achieve a high-force actuator. This situation compromises the performance of the injector, because the high moving mass of the armature makes the valve needle heavy and slows the operation of the injector. As will be appreciated, as the fuel pressure required in fuel injection systems increases, more powerful solenoids are required, and the use of such solenoid actuators in a direct-acting configuration becomes impractical.

[0008] In recognition of this problem, common rail fuel injectors have historically used a hydraulic servo mechanism (e.g. a power assistance) in order to open and close the needle. Examples of such mechanisms are described in EP 0647780 and EP 0740068.

[0009] A solenoid-actuated hydraulic servo fuel injector such as that of EP 0740068 is illustrated in Figure 2. The fuel injector 1 comprises a valve body 3 defining a blind bore 5 that terminates at a nozzle region 7; and an elongate valve needle 9 having a tip region 11 that is slidable within the bore 5, such that the tip 11 can engage and disengage a valve seat 13 defined by an inner surface of the nozzle 7. The nozzle 7 is provided with one or more apertures (or spray holes; not shown) in communication with the bore 5. Engagement of the tip 11 with the valve seat 13 prevents fluid escaping from the valve body 3 through the apertures, and when the tip 11 is lifted from the valve seat 13, fluid may be delivered through the apertures into an associated engine cylinder (not shown).

[0010] A control chamber 21 for the valve needle 9 communicates with a high pressure fuel line 17 through a restrictor 23, with an end of the valve needle 9 being exposed to fuel pressure in the control chamber 21. A control valve for the control chamber 21, including a valve member 37, is operable to control whether fuel pressure within the control chamber 21 is at a relatively high level, in which case the valve needle 9 remains seated against the valve seat 13 and no injection takes place, or whether fuel pressure is reduced to a sufficiently low level to allow the valve needle 9 to lift from the valve seat 13 to commence injection through the apertures. A solenoid actuator 45 is provided to control movement of the valve member 37 via an armature (not labelled in Figure 2).

[0011] A solenoid-actuated hydraulic servo mechanism such as that of Figure 2 means that a low force control valve 37 can be used to switch the high forces on the valve needle 9. With low forces on the control valve 37, a relatively inexpensive, compact and simple solenoid can give a suitably fast enough response in the injector for most purposes. However, a number of disadvantages are associated with the design of such servo injector mechanisms. In this regard, prior art servo designs are subject to a lag period between energisation of the solenoid and commencement of the fuel injection event, during which a parasitic flow of fuel is channelled to a low-pressure fuel drain. Therefore, a hydraulic servo injector cannot always be made to commence a fuel in-

jection event as quickly as may be desired. Moreover, the faster the response desired, the higher the fuel flows required for the hydraulic servo and the higher the resulting parasitic losses from the servo mechanism. The parasitic fuel flow also undesirably returns heat to the fuel supply.

[0012] US 2003/0116657 and WO 03/040546 describe solenoid-actuated injectors in which a hydraulic servo mechanism is not present. Instead, first and second solenoid actuators are directly coupled to the valve needle. The first solenoid actuator operates over a relatively short stroke, and the second solenoid actuator operates over a relatively long stroke. The first solenoid actuator is arranged to decouple from the valve needle in response to initial opening movement of the valve needle, and the second solenoid actuator carries the valve needle to its full lift position.

[0013] More recently, some injectors have used a piezoelectric actuator to directly move the needle (e.g. EP 0995901; EP 1174615). These designs eliminate both the parasitic losses from the servo flows and the time delays in the servo. Some of them also have an accumulator volume within the injector, which ensures that maximum pressure is available at the nozzle seat, and that wave activity (which could interfere with multiple injections) is minimised.

[0014] As illustrated in Figure 3, a known piezoelectrically actuated fuel injector may comprise a valve body 3 having a blind bore 5 extending into a nozzle region 7 provided with a plurality of apertures (or fuel spray holes; not shown); and a valve needle 9 reciprocable within the bore 5 between injecting and non-injecting positions, as previously described.

[0015] A piezoelectric actuator stack 49 is operable to control the position occupied by a control piston 51, the piston 51 being moveable to control the fuel pressure within a control chamber 53 defined by a surface associated with the valve needle 9 of the injector and a surface of the control piston 51. The piezoelectric actuator stack 49 comprises a stack of piezoelectric elements, the energisation level, and hence the axial length, of the stack being controlled by applying a voltage across the stack.

[0016] Upon de-energisation of the piezoelectric stack 49, the axial length of the stack is reduced and the control piston 51 is moved in a direction which causes the volume of the control chamber 53 to be increased, thereby causing fuel pressure within the control chamber 53 to be reduced. The force applied to the valve needle 9 due to fuel pressure in the control chamber 53 is thus reduced, causing the valve needle 9 to lift away from a valve needle seating (not shown) under the influence of high-pressure fuel on surfaces of the valve needle 9, so as to permit fuel delivery into an associated engine cylinder via one or more apertures (or spray holes; not shown).

[0017] To terminate a fuel injection event, the stack 49 is returned to its initial energisation state, and as a result, the piston 51 also returns substantially to its initial position thereby reducing the volume of the control chamber 53. The consequential increase in fuel pressure within the control chamber 53 applies an increased closing force on the valve needle 9, and a point is eventually reached at which the fuel pressure within the control chamber 53 in conjunction with the spring 29 is sufficient to return the needle 9 into engagement with the valve seating (not shown).

[0018] In the piezoelectric fuel injector illustrated in Figure 3, the control piston 51 is part of a hydraulic amplifier system situated between the actuator stack 49 and the needle 9, such that axial movement of the actuator 49 results in an amplified axial movement of the needle 9. In contrast to the fuel injector illustrated in Figure 3, some piezoelectrically-actuated fuel injectors may be of the type in which energisation (rather than de-energisation) of the piezoelectric stack is required to initiate a fuel injection event.

[0019] In addition to the potential faster injector response time of the piezoelectrically operated valve, a further benefit of using a piezoelectric actuator for direct control over the movement of a valve needle is that the axial length of the piezoelectric stack can be variably controlled by changing the amount of electrical charge stored on the piezoelectric stack and, therefore, it is possible to control the position of the valve needle relative to the valve seat. In this way, piezoelectric fuel injectors offer greater ability to meter the amount of fuel that is injected.

[0020] However, a number of disadvantages of direct-acting piezoelectric fuel injectors are also apparent. For example, one problem with these direct acting designs is that a relatively large and expensive piezoelectric actuator is needed to provide the energy needed initially to lift the needle but, as for a direct-acting solenoid actuator, a large retracting force continues to be applied to the valve needle 9 throughout the opening movement, until the valve needle 9 reaches its full lift position. Consequently, such injectors tend to be relatively inefficient as a significant amount of energy is wasted in applying a large, unnecessary retracting force to the valve needle 9 throughout its full range of movement.

[0021] Furthermore, this type of actuator needs to get larger and/or more efficient as nozzle flow requirements and pressures increase. Another consideration with respect to large fuel injections is that the amount of needle lift is limited by the capabilities of the actuator (even if a hydraulic amplifier is used to try to alleviate this problem).

[0022] Against this background, it would be desirable to provide a fuel injector having an improved actuator arrangement that alleviates or overcomes some of the above-mentioned problems.

SUMMARY OF THE INVENTION

[0023] The present invention resides in a fuel injector for use in an internal combustion engine, the fuel injector comprising an injection nozzle having a nozzle body provided with a nozzle bore, a valve needle being received within the nozzle bore and engageable with a seat region

to control fuel delivery through at least one nozzle outlet, and first and second actuator arrangements. At least the first actuator arrangement is operable to apply an opening force to the valve needle thereby to cause an opening movement of the valve needle, and the first actuator arrangement is configured to decouple from the valve needle in response to the opening movement.

[0024] The first actuator arrangement comprises a solenoid actuator having a first armature that is slidable with respect to the valve needle, and a first core member, arranged such that the first armature moves towards the first core member upon operation of the first actuator arrangement. The valve needle carries a coupling member that is arranged to decouple from the first armature in response to said opening movement of the valve needle, and the coupling member and the first armature are separated by a clearance when the valve needle is engaged with the seat region, such that the coupling member and the first armature are arranged to couple with one another in response to operation of the first actuator arrangement, thereby to cause said opening movement of the valve needle upon movement of the first armature towards the first core member.

[0025] Because the first actuator arrangement can decouple from the valve needle, a fuel injector according to the present invention can be provided with first and second actuator arrangements that operate on the valve needle in an independent or partly independent manner. This allows the first and second actuator arrangements to be designed so as to perform different functions in operating the injector.

[0026] For example, in a preferred embodiment, the first actuator arrangement is operable to cause initial lifting of the valve needle and then to decouple from the valve needle in response to said opening movement, and the second actuator arrangement is operable to assist said initial movement and then to carry the valve needle to a full lift position.

[0027] In this configuration, the first actuator arrangement can be optimised so as to provide an initial lifting force to the valve needle without being required to carry the valve needle to a full lift position. Similarly, the second actuator arrangement can be optimised so as to carry the valve needle to a full lift position, without needing also to provide an initial lifting force. Advantageously, therefore, the first and second actuator arrangements can each be substantially smaller than if only one actuator of a similar type were provided. Furthermore, the first and second actuator arrangements can likewise be smaller than would be required if the first actuator were not arranged to decouple from the valve needle.

[0028] Preferably, both the first and second actuator arrangements are operable to apply an opening force to the valve needle thereby to cause an opening movement of the valve needle.

[0029] The first armature may comprise a bearing sleeve having an internal bore, the surface of the internal bore being in sliding contact with the valve needle. The bearing sleeve may, for example, advantageously limit the movement of the first armature towards and/or away from the first core member, thereby to allow fine adjustment of the operation of the first actuator arrangement.

[0030] Because the coupling member and the first armature are separated by a clearance when the valve needle is engaged with the seat region, the first armature can be arranged to accelerate towards the coupling member before coupling thereto, so that, when coupling occurs, the first armature imparts a high-impulse force to the valve needle.

[0031] The fuel injector may comprise a lift stop arranged to limit movement of the first armature towards the first core member so as to cause decoupling of the first armature from the valve needle upon opening movement thereof. The provision of a lift stop allows the point at which decoupling of the first armature and the valve needle occurs to be finely controlled.

[0032] The valve needle may include a thrust collar, and needle biasing means that act on the thrust collar to bias the valve needle into engagement with the seat region. The fuel injector may further include armature biasing means to bias the first armature away from the thrust collar.

[0033] The second actuator arrangement may comprise a solenoid actuator having a second armature and a second core member, arranged such that the second armature moves towards the second core member upon operation of the second actuator arrangement, wherein the second armature is fixed with respect to the valve needle. In this way, the second actuator arrangement is directly coupled to the valve needle, and can be configured to lift the valve needle to a full lift position.

[0034] Conveniently, the valve needle may extend axially through the first actuator arrangement to cooperate with the second actuator arrangement.

[0035] The fuel injector may comprise spacing means to space the first actuator arrangement from the nozzle body and/or spacing means to space the second actuator arrangement from the first actuator arrangement. During manufacture of such a fuel injector, the spacing means could be chosen so as to adjust the stroke of the respective actuator means.

[0036] A fuel injector according to the present invention may comprise one or more further actuator arrangements, in addition to the first and second actuator arrangements described above. For example, provision of such further actuator arrangements would allow relatively larger forces to be applied to the valve needle.

BRIEF DESCRIPTION OF THE DRAWINGS

[0037] Figure 1, which is a plot of force against needle lift for a fuel injector having a directly-acting solenoid actuator, and Figures 2 and 3, which show fuel injectors known in the art, have already been referred to above. The present invention will now be described, by way of example only, with reference to the remaining accompa-

nying drawings, in which like reference numerals are used for like parts, and in which:

Figure 4 is a cross-sectional view of a fuel injector according to one embodiment of the present invention;

Figure 5a is a cross-sectional view on an enlarged scale of part of the fuel injector of Figure 4, in a first operational state, and Figure 5b is a still further enlarged portion of Figure 5a;

Figure 6 is a cross-sectional view similar to that of Figure 5b, showing the fuel injector of Figure 4 in a second operational state;

Figure 7 is a cross-sectional view similar to that of Figure 5b, showing the fuel injector of Figure 4 in a third operational state;

Figure 8a is a cross-sectional view similar to that of Figure 5a, showing the fuel injector of Figure 4 in a fourth operational state, and Figure 8b is a still further enlarged portion of Figure 8a;

Figure 9 is a plot showing, schematically, how force varies with needle lift in the fuel injector of Figure 4; and

Figure 10 is a plot showing, schematically, how force varies with needle lift in a variant of the fuel injector of Figure 4.

[0038] Throughout this description, terms such as 'top', 'bottom', 'upper' and 'lower' are used with reference to the orientation of the fuel injector as shown in the accompanying drawings. However, it will be appreciated that such references are not limiting and that fuel injectors according to the invention could be used in any orientation.

DETAILED DESCRIPTION OF THE INVENTION

[0039] Figure 4 shows a fuel injector in accordance with one embodiment of the present invention. The fuel injector 100 is generally elongate in form and includes a nozzle holder 102 (the upper end of the injector in the orientation shown in the figures) and a cap nut 104 connected to a lower end of the nozzle holder 102. More specifically, the nozzle holder 102 includes a downwardly depending tubular portion 106 defining an open end 108 which cooperates by way of a screw thread arrangement with an open upper end of a tubular wall 110 of the cap nut 104. The internal surfaces of the tubular walls of the nozzle holder 102 and the cap nut 104 define an elongate cylindrical chamber 112 for housing the operating components of the fuel injector 100, as will be described further herein.

[0040] A fuel inlet socket 114 is provided at the upper end of the nozzle holder 102 which connects to a pressurised fuel source (not shown), in use. Although not shown in Figure 4, a fuel supply line extends from the fuel inlet socket 114 and opens into the injector chamber 112 thus supplying high pressure fuel thereto.

[0041] Referring additionally to Figures 5a and 5b, an injection nozzle 118 is housed at the lowermost end of the chamber 112 and includes a nozzle body 120 having a wide diameter region 120a located within the chamber 112 and a narrow diameter region 120b that projects through an aperture 122 defined in the bottom end of the cap nut 104. An o-ring seal member 121 is positioned at a shoulder defined at the peripheral edge of the aperture 122 and is compressed by the wide diameter region 120a of the nozzle body 120 so as to provide a seal against fuel escaping from the injector chamber 112.

[0042] The narrow diameter region 120b defines a nozzle tip region 124 that is provided with a set of nozzle outlets 126. Only one nozzle outlet 126 is shown in the figures, but it will be appreciated that the set of nozzle outlets 126 may comprise any suitable number of such outlets. Although not shown in the figures, in use the tip 124 projects into a combustion cylinder of an engine to deliver pressurised fuel to it through the set of nozzle outlets 126.

[0043] As shown most clearly in Figure 5a, the nozzle body 120 is provided with an axially extending blind bore 130, the blind end of which is shaped to define a conical surface 132 in the vicinity of the nozzle tip 124. The nozzle bore 130 houses a nozzle valve member 134 in the form of an elongate needle. The tip of the valve needle 134 is engageable with a seat region 137, which is defined by the conical surface 132 of the nozzle bore 130, to control the delivery of fuel through the nozzle outlets 126.

[0044] An annular plug 140 is fixedly mounted within the bore 130 of the nozzle body 120, in the wide diameter region 120a of the nozzle body 120. The annular plug 140 includes a through-bore within which the valve needle 134 is a close sliding fit. The annular plug 140 therefore acts as a bearing to guide axial movement of the valve needle 134 within the injector, and to guard against lateral movement of the needle 134 away from its central position within the nozzle body 120.

[0045] The bore 130 of the nozzle body 120 is shaped to define an annular gallery 142 approximately mid-way along the length of the nozzle body 120. The annular plug 140 terminates at its lowermost end (in the orientation of Figures 5a and 5b) with a conically-tapered section 144, which lies adjacent to the annular gallery 142. The annular gallery 142 communicates with the injector chamber 112 by way of a plurality of laterally-extending passages 146, two of which are shown in Figure 5a.

[0046] In use, high-pressure fuel is supplied to the annular gallery 142 by way of the injector chamber 112 and the laterally-extending passages 146. The valve needle 134 has a smaller diameter than the bore 130 of the nozzle body 120, so that high-pressure fuel can flow from

the gallery 142 to the nozzle tip 124 through an annular clearance defined between the valve needle 134 and the nozzle body bore 130.

[0047] The injector chamber 112 houses a first actuator arrangement, generally indicated at 150, and a second actuator arrangement, generally indicated at 152. The first and second actuator arrangements 150, 152 are arranged in a stack, so that the first actuator arrangement 150 is located between the nozzle body 120 and the second actuator arrangement 152. The first and second actuator arrangements 150, 152 are held at the lower end of the injector chamber 112 by means of a compression spring 113 and a rod 115, as shown most clearly in Figure 4.

[0048] The first actuator arrangement 150 includes a solenoid core member 154 which is annular in form and has a generally T-shaped cross section so as to define a relatively wide upper core portion 154a and a relatively narrow lower core portion 154b. A solenoid 156 is formed around the lower core portion 154b and mounted on a non-conductive coil former 158 in a known manner. A cup-shaped outer pole piece 160 fits over the lower core region 154b and provides an outer pole of the actuator arrangement 150 whilst the lower end surface of the core member 154 provides an inner pole.

[0049] The first actuator arrangement 150 is spaced apart from the upper end face of the nozzle body 120 by a shim 162 which defines a volume 164 between the two components. The shim 162 is provided with apertures 166 so that pressurised fuel can enter the volume 164 from the injector chamber 112. The first actuator arrangement 150 and the shim 162 are held in place by a clamping ring 163, which embraces the lowermost end of the actuator arrangement 150 and the uppermost end of the nozzle body 120 and holds the shim 162 therebetween. The clamping ring 163 includes apertures 165 so that pressurised fuel can flow through the apertures 166 in the shim 162.

[0050] As shown most clearly in Figure 5b, the volume 164 houses a disc-shaped armature 168, known hereafter as a sliding armature, that defines a substantially flat upper surface which opposes the outer and inner poles of the first actuator arrangement 150. The sliding armature 168 includes vent holes 170 adjacent its periphery, which reduce the hydrodynamic drag of the armature as it moves within the fluid-filled volume 164.

[0051] The sliding armature 168 has a central opening 172, which has a bearing sleeve 174 mounted therein. An upper region of the valve needle 134 passes through the bearing sleeve 174. The valve needle 134 can slide within the bearing sleeve 174, so that the sliding armature 168 and the valve needle 134 can move axially with respect to one another. In other words, the sliding armature 168 can slide along the length of the valve needle 134.

[0052] The valve needle 134 extends upwardly through the bearing sleeve 174, and through a central bore 176 in the core member 154. A disc-shaped plate 178 is provided on top of the core member 154, so as to partly close the central bore 176. The plate 178 is provided with a central aperture 180, through which the valve needle 134 is accommodated. In this way, the valve needle 134 extends axially through the first actuator arrangement 150 and, as will be described in more detail below, the upper end 182 of the valve needle 134 is located within a second fluid-filled volume 184 between the first and second actuator arrangements 150, 152.

[0053] A first biasing spring 186, in the form of a compression spring, is located annularly around the valve needle 134 within the central bore 176 of the core member 154. The uppermost end of the first biasing spring 186 acts against a washer 188, which is held against the plate 178 to act as an end stop for the spring. The lowermost end of the biasing spring 186 acts against a thrust collar 190, which is mounted securely on the valve needle 134 at a position approximately half-way along the length of the bore 176. The first biasing spring 186 urges the valve needle 134 downwards, to bias the tip of the valve needle 134 into engagement with the seat region 137 of the nozzle body 120.

[0054] A further collar, known hereafter as an anvil 192, is positioned on and securely attached to the valve needle 134 below the thrust collar 190. When the valve needle 134 is seated, as in Figures 5a and 5b, a majority of the anvil 192 is positioned within the bore 176 of the core member 154. However, a relatively short, lowermost portion of the anvil 192 extends beyond the lower face of the core member 154, and thereby extends a short way into the fluid-filled volume 164.

[0055] A second biasing spring 194, in the form of a compression spring, is arranged annularly around the part of the valve needle 134 that carries the anvil 192. The uppermost end of the second biasing spring 194 acts against the lowermost face of the thrust collar 190, while the lowermost end of the second biasing spring 194 acts against the top surface of the bearing sleeve 174. In this way, the second biasing spring 194 acts to bias the bearing sleeve 174, and hence the sliding armature 168, in a downwardly direction away from the core member 154. When the first actuator arrangement 150 is not energised, the lowermost surface of the bearing sleeve 174 abuts the uppermost surface of the annular plug 140, so as to define an initial position for the sliding armature 168.

[0056] A lift stop 196, in the form of a cylindrical sleeve, is located in an enlarged-diameter, lower portion of the bore 176. The second biasing spring 194 is a sliding fit within the lift stop 196 and around the anvil 192.

[0057] The second actuator arrangement 152 includes an annular solenoid core member 202 which is similar to the core member 154 of the first actuator arrangement. The core member 202 therefore has a generally T-shaped cross section so as to define a relatively wide upper core portion 202a and a relatively narrow lower core portion 202b. A solenoid 204 is formed around the lower core portion 202b and mounted on a non-conductive coil former 206 in a known manner. A cup-shaped outer pole piece 208 fits over the lower core region 202b

and provides an outer pole of the second actuator arrangement 152 whilst the lower end surface of the core member 202 provides an inner pole.

[0058] The core member 202 of the second actuator arrangement 152 includes a central bore 220, which has an upper, relatively small diameter region and a lower, relatively large diameter region. The relatively large diameter region of the bore 220 receives a post 222. As will be described in more detail below, the bottom face of the post 222 acts as a stop for the end 182 of the valve needle 134.

[0059] The second actuator arrangement 152 is spaced apart from the first actuator arrangement 150 using a further shim 210, held in place by a further clamping ring 212. The shim 210 and clamping ring 212 each include apertures to allow pressurised fuel to flow into the volume 184 between the actuator arrangements 150, 152 and enclosed, in part, by the shim 210.

[0060] The volume 184 houses a disc-shaped armature 214, known hereafter as a fixed armature 214, that defines a substantially flat upper surface which opposes the outer and inner poles of the second actuator arrangement 152. The fixed armature 214 includes vent holes 216 adjacent its periphery, which reduce the hydrodynamic drag of the armature as it moves within the fluid-filled volume 184.

[0061] The uppermost end 182 of the valve needle 134 is received within a central aperture 218 of the armature 214. The fixed armature 214 is securely coupled to, or fixed to, the valve needle 134 so that movement of the fixed armature 214 causes movement of the valve needle 134. The fixed armature 214 may be coupled to the end 182 of the valve needle 134 for example by providing inter-engaging screw threads on each component, by press-fitting or welding the components together, or by other suitable means.

[0062] Operation of the fuel injector will now be described. In the usual manner, the energisation state of each actuator arrangement 150, 152 controls the movement of the corresponding armature 168, 214 towards and away from the respective core members 154, 202.

[0063] As noted above, Figures 5a and 5b show the fuel injector in a non-injecting state, in which the valve needle 134 is seated on the seat region 137 of the nozzle body 120. In this state, the first and second actuator arrangements 150, 152 are not energised (i.e. no current is supplied to the solenoids 156, 204). Opening movement of the valve needle 134 occurs when the actuator arrangements 150, 152 are energised. This will now be described with reference to Figures 6 and 7, which show the injector components in two successive intermediate stages of the valve opening movement, and to Figures 8a and 8b which show the position of the injector components when the valve needle 134 is in its fully-open position.

[0064] As shown most clearly in Figure 5b, with the needle 134 in its closed position, there is a small clearance 224 between the bottom of the anvil 192 and the top surface of the bearing sleeve 174. Upon energisation of the first actuator arrangement 150, the sliding armature 168 moves towards the core member 154, against the biasing force of the second spring 194. By virtue of the clearance 224, the sliding armature 168 and bearing sleeve 174 are free to slide upwards on the valve needle 134 for a short distance. The sliding armature 168 thereby accelerates towards the core member 154, while the valve needle 134 remains seated.

[0065] Once the clearance 224 between the bearing sleeve 174 and the anvil 192 has closed, the bearing sleeve 174 strikes the anvil 192, as shown in Figure 6. The valve needle 134 is thereby effectively coupled to the sliding armature 168, by way of the anvil 192 and the bearing sleeve 174. In this way, the anvil 192 acts as a coupling member to couple the sliding armature 168 to the valve needle 134. Further movement of the sliding armature 168 towards the core member 154 therefore causes the valve needle 134 to move in an upward direction, against the biasing force of the first biasing spring 186. In this way, the valve needle 134 begins to lift away from the valve seat 137.

[0066] It will be appreciated that, when the accelerating bearing sleeve 174 strikes the anvil 192, an impact force or impulse is transferred to the valve needle 134 that may be sufficient to give rise to an initial upward movement of the valve needle 134. This initial movement may cause the anvil 192 briefly to bounce off the bearing sleeve 174. Continued movement of the sliding armature 168 towards the core member 154 then brings the bearing sleeve 174 back into contact with the anvil 192, so as to couple the armature 168 to the valve needle 134.

[0067] As shown in Figure 7, upward movement of the sliding armature 168 is eventually stopped when the uppermost face of the bearing sleeve 174 comes into contact with the lowermost face of the lift stop 196. At this intermediate stage of opening, the valve needle 134 has lifted slightly from the seat region 137 (not shown in Figure 7).

[0068] It will be appreciated that, since the position of the uppermost face of the bearing sleeve 174 relative to the sliding armature 168 and the position of the lower face of the lift stop 196 relative to the core member 154 can be accurately controlled during manufacture of the injector, the point at which upward movement of the sliding armature 168 ceases can be precisely controlled.

[0069] Further opening movement of the valve needle 134 occurs by virtue of the second actuator arrangement 152. When the solenoid 204 of the second actuator arrangement 152 is energised, the fixed armature 214 is caused to move towards the core member 202 of the second actuator arrangement 152. Since the fixed armature 214 is coupled to the valve needle 134, the valve needle 134 is lifted directly by operation of the actuator arrangement 152.

[0070] Figures 8a and 8b show the injector when the valve needle 134 is in its fully lifted position. As seen in Figure 8a, the tip of the valve needle 134 is lifted from

the seat region 137 of the nozzle body 120, so that pressurised fuel can flow from the injector chamber 112 through the nozzle outlets 126, via the passages 146 and the bore 130 of the nozzle body 120.

[0071] As shown most clearly in Figure 8b, the anvil 192 of the valve needle 134 has been lifted clear of the bearing sleeve 174 so that, during the further upward movement of the valve needle 134 that takes place after the bearing sleeve 174 contacts the lift stop 196, the needle 134 moves independently of the sliding armature 168. In this way, the first actuator arrangement 150 is decoupled from the valve needle 134.

[0072] The fully-lifted position of the valve needle 134 is reached when the uppermost end 182 of the valve needle 134 comes into contact with the post 222, as shown in Figures 8a and 8b.

[0073] In this embodiment of the invention, the first and second actuator arrangements 150, 152 are energised simultaneously by the same electrical supply. It will be understood, therefore, that the second actuator arrangement 152 provides an assisting upward force on the valve needle 134 also while the first actuator arrangement 150 is coupled to the valve needle 134.

[0074] Closing movement of the valve needle 134 takes place when the actuator arrangements 150, 152 are de-energised. The first biasing spring 186 acts on the thrust collar 190 of the valve needle 134, so as to reseat the valve needle 134 on the seat region 137 of the nozzle body 120. The second biasing spring 194 acts on the bearing sleeve 174 so as to return the sliding armature 168 to its initial position, with the bearing sleeve 174 in contact with the top of the annular plug 140.

[0075] As described above, the opening movement of the valve needle 134 is achieved by the first and second actuator arrangements 150, 152 acting separately on the valve needle 134. The first actuator arrangement 150 is optimised to cause initial lifting of the valve needle 134, and then to decouple from the valve needle 134. The second actuator arrangement 152 is optimised to assist the initial movement, and then to carry the valve needle 134 to its full lift position.

[0076] The first actuator arrangement 150 can therefore be configured with a small air gap between the core member 154 and the sliding armature 168 when in its initial position, since the first actuator arrangement 150 does not need to lift the needle 134 to its full lift position. Instead, the first actuator arrangement 150 can impart a relatively large initial lifting force to the valve needle 134 only over a relatively short distance. The first actuator arrangement 150 can therefore be substantially smaller than would be required if this actuator arrangement were also responsible for lifting the needle 134 to its full lift position.

[0077] Similarly, because the second actuator arrangement 152 need not provide sufficient force to the valve needle 134 to cause initial lifting movement of the needle 134, the second actuator arrangement 152 can be substantially smaller than would otherwise be the case.

[0078] In this way, the arrangement of the present invention allows two relatively small solenoid actuator arrangements to be used in place of one much larger solenoid actuator.

[0079] Figure 9 is a schematic plot of force versus needle position for the embodiment of the invention shown in Figures 4 to 8b, for comparison with Figure 1. As in Figure 1, the decreasing force required to move the valve needle 134 as a function of the needle position (i.e. the magnitude of the needle lift above its fully-seated position) is shown as curve N in Figure 1.

[0080] Curve S1 in Figure 9 shows the force applied to the valve needle 134 by the first actuator arrangement 150. As described above, the high initial force required to cause initial movement of the needle 134 is obtained by allowing the sliding armature 168 to accelerate towards the core member 154, closing the clearance 224, before the armature 168 couples with the valve needle 134. Thus the sliding armature 168 undergoes a pre-travel phase, in which the sliding armature 168 travels alone without coupling to the valve needle 134. As the sliding armature 168 accelerates during the pre-travel phase, the armature 168 builds up kinetic energy and, upon impact of the bearing sleeve 174 with the anvil 192, the kinetic energy is transformed into a high-impact force over a short distance. The effective force achieved in this way is labelled A in Figure 9. Consequently, a solenoid with a relatively low basic force characteristic can be used to generate a force impulse capable of initially unseating the valve needle 134.

[0081] In order to maximise the transfer of kinetic energy from the sliding armature 168 to the valve needle 134, it is important that the mass of the valve needle 134 plus the fixed armature 214 is of similar mass to that of the sliding armature 168 plus the bearing sleeve 174. Thus the valve needle 134 must be relatively light. This is achieved by providing a valve needle 134 having a relatively small diameter, and providing the annular plug 140 with a bore to guide the valve needle 134 within the nozzle body 120 as previously described.

[0082] At point D on the curve, the first actuator arrangement 150 decouples from the valve needle 134. Curve S2 shows the force applied to the valve needle 134 by the second actuator arrangement 152, from which it will be seen that the second actuator arrangement 152 provides sufficient force to carry the valve needle 152 to its full lift position.

[0083] As will be appreciated by comparing Figure 9 with Figure 1, the force applied to the valve needle by the two actuator arrangements is much more closely matched to the actual force required to lift the valve needle than in previous injector arrangements. The present invention therefore provides a compact injector with a high response speed.

[0084] In a variant of the fuel injector shown in Figures 4 to 8b, when the valve needle is seated, there is no clearance between the bearing sleeve 174 and the anvil

192. In this way, the first actuator arrangement 150 is initially coupled to the valve needle 134, and the sliding armature 168 does not undergo a pre-travel phase when the first actuator arrangement is energised.

[0085] The force versus needle lift characteristics of this variant are shown in Figure 10, from which it can be appreciated that the basic force characteristic of the first actuator arrangement, labelled S1 in Figure 10, must be sufficiently large to cause initial unseating movement of the valve needle 134. As before, the first actuator arrangement decouples at point D, and the valve needle 134 is carried to full lift by the force S2 applied directly to the valve needle 134 by the second actuator arrangement 152.

[0086] Although the force applied to the valve needle by the two actuator arrangements in this variant is not as well matched to the actual force required to lift the needle as in the embodiment of Figures 4 to 8b, it will nevertheless be appreciated that this variant, which does not form part of the present invention, still offers a considerable improvement over the situation shown in Figure 1.

[0087] A number of other variations and modifications to the invention are also possible without departing from the scope of the invention as set out in the appended claims, as will now be described.

[0088] It will be appreciated that the performance of a fuel injector according to the invention is dependent on the characteristics of the stroke of the valve needle 134, such as the point at which the first actuator arrangement 150 decouples from the valve needle 134, and the amount of travel that the valve needle 134 undergoes from its fully seated to fully open positions. Consequently, it may be desirable to adjust these, and other, characteristics of an injector during its manufacture. Such adjustments can be achieved by providing selectable-thickness components that can be selected during manufacture to optimise the desired characteristics. For example, adjustment of the stroke of the sliding armature 168 can be achieved by providing selectable-thickness shims 162 for spacing the first actuator arrangement 150 from the nozzle body 120. Similarly, adjustment of the full needle lift distance can be achieved by providing selectable-thickness shims 210 for spacing the first and second actuator arrangements.

[0089] Many components of the injector shown in Figures 4 to 8b are described as separate components, and it will be appreciated that this arrangement also provides a large degree of adjustability during manufacture of the injector. However, where such adjustability is not required or can be otherwise achieved, it may be desirable to integrally form two or more components. For example, the thrust collar 190 and/or the anvil 192 could be integrally formed with the valve needle 134. Similarly, the bearing sleeve 174 may be integrally formed with the sliding armature 168. The bearing sleeve 174 may instead be formed as a wear-resistant coating on the sliding armature 168.

[0090] In the embodiments described above, both actuator arrangements 150, 152 are energised and de-energised simultaneously using a single electrical supply or drive, which is the lowest-cost arrangement. However, it will be appreciated that each actuator arrangement could instead be controlled separately by independent electrical drives. Using multiple drives in this way allows increased control of the valve needle movement. For example, by energising only the first actuator arrangement 150, the valve needle 134 could be held in a part-lifted position intermediate between the closed and fully open positions. This position could be utilised for delivering small injection quantities. The needle could then be lifted to the fully open position for delivery of larger quantities by energising the second actuator arrangement 152.

[0091] The force characteristics of each actuator arrangement 150, 152 can be adapted to optimise the performance of the injector. For example, it may be desirable that the solenoid coil 156 of the first actuator arrangement 150 has relatively few turns, so that the inductance of the solenoid 156 is relatively low to ensure rapid current rise. This configuration would give the first actuator arrangement 150 a rapid response time, which would for example be useful for providing closely-spaced pilot or post injections. The solenoid coil 204 of the second actuator arrangement 152, meanwhile, may have a relatively large number of turns, since it is not necessary for the second actuator arrangement 152 to respond rapidly.

[0092] Although the invention has been described with reference to two actuator arrangements, it will be appreciated that one or more additional actuator arrangements could be provided, so that the injector includes three, four, five or more actuator arrangements in a stack, with the valve needle passing through a central bore in each actuator arrangement as necessary. Such additional actuator arrangements may be desirable where more force is required to operate the injector, or where it is desirable to use even smaller actuator arrangements to reduce the diameter of the injector.

[0093] One or more additional actuator arrangements could be arranged to couple and/or decouple from the valve needle, in a similar way to the first actuator arrangement of the embodiment shown in Figures 4 to 8b. Alternatively, or in addition, one or more additional actuator arrangements could be directly coupled to the valve needle, in a similar way to the second actuator arrangement of the embodiment shown in Figures 4 to 8b.

[0094] As when two actuator arrangements are provided, a stack of three or more actuator arrangements may be energised simultaneously. Alternatively, by providing each actuator arrangement with its own electrical drive, the actuator arrangements could be energised selectively, or in sequence. In particular, when two or more actuator arrangements having sliding armatures are provided, the sliding armatures could be made to impact the valve needle simultaneously to generate a high impact force for initial unseating of the valve needle, or the sliding armatures could be made to impact the valve needle sequentially to lift the needle over a greater distance.

Claims

1. A fuel injector (100) for use in an internal combustion engine, the fuel injector (100) comprising:

   an injection nozzle having a nozzle body (120) provided with a nozzle bore (130);
   a valve needle (134) being received within the nozzle bore (130) and engageable with a seat region (137) to control fuel delivery through at least one nozzle outlet (126); and
   first and second actuator arrangements (150, 152), at least the first actuator arrangement (150, 152) being operable to apply an opening force to the valve needle (134) thereby to cause an opening movement of the valve needle (134);
   wherein the first actuator arrangement (150) comprises a solenoid actuator having a first armature (168) that is slidable with respect to the valve needle (134), and a first core member (154), arranged such that the first armature (168) moves towards the first core member (154) upon operation of the first actuator arrangement (150);
   and wherein the valve needle (134) carries a coupling member (192) that is arranged to decouple from the first armature (168) in response to said opening movement of the valve needle (134);

   characterised in that the coupling member (192) and the first armature (168) are separated by a clearance (224) when the valve needle (134) is engaged with the seat region (137), such that the coupling member (192) and the first armature (168) are arranged to couple with one another in response to operation of the first actuator arrangement (150), thereby to cause said opening movement of the valve needle (134) upon movement of the first armature (168) towards the first core member (154).

2. The fuel injector of Claim 1, wherein the first actuator arrangement (150) is operable to cause initial lifting of the valve needle (134) and then to decouple from the valve needle (134) in response to said opening movement, and the second actuator arrangement (152) is operable to assist said initial movement and then to carry the valve needle (134) to a full lift position.

3. The fuel injector of Claim 1 or Claim 2, wherein both the first and second actuator arrangements (150, 152) are operable to apply an opening force to the valve needle (134) thereby to cause an opening movement of the valve needle (134).

4. The fuel injector of any preceding claim, wherein the first armature (168) comprises a bearing sleeve (174) having an internal bore, the surface of the internal bore being in sliding contact with the valve needle (134).

5. The fuel injector of any preceding claim, comprising a lift stop (196) arranged to limit movement of the first armature (168) towards the first core member (154) so as to cause decoupling of the first armature (168) from the valve needle (134) upon opening movement thereof.

6. The fuel injector of any preceding claim, wherein the valve needle (134) includes a thrust collar (190), and needle biasing means (186) that act on the thrust collar (190) to bias the valve needle (134) into engagement with the seat region (137).

7. The fuel injector of Claim 6, further including armature biasing means (194) to bias the first armature (168) away from the thrust collar (190).

8. The fuel injector of any preceding claim, wherein the second actuator arrangement (152) comprises a solenoid actuator having a second armature (214) and a second core member (202), arranged such that the second armature (214) moves towards the second core member (154) upon operation of the second actuator arrangement (152), and wherein the second armature (214) is fixed with respect to the valve needle (134).

9. The fuel injector of any preceding claim, wherein the valve needle (134) extends axially through the first actuator arrangement (150) to cooperate with the second actuator arrangement (152).

10. The fuel injector of any preceding claim, comprising spacing means (162) to space the first actuator arrangement (150) from the nozzle body (120) and/or spacing means (210) to space the second actuator arrangement (152) from the first actuator arrangement (150).

11. The fuel injector of any preceding claim, comprising one or more further actuator arrangements.

Patentansprüche

1. Kraftstoffeinspritzvorrichtung (100) zur Verwendung in einer Verbrennungskraftmaschine, wobei die Kraftstoffeinspritzvorrichtung (100) Folgendes umfasst:

   eine Einspritzdüse, die einen Düsenkörper (120) hat, der mit einer Düsenbohrung (130) versehen ist,
   eine Ventilnadel (134), die in der Düsenbohrung

(130) aufgenommen ist und mit einer Sitzregion (137) in Eingriff gebracht werden kann, um die Kraftstoffabgabe durch wenigstens einen Düsenauslass (126) zu regeln, und
eine erste und eine zweite Aktoranordnung (150, 152), wobei wenigstens die erste Aktoranordnung (150, 152) zum Anwendet einer Öffnungskraft auf die Ventilnadel (134) funktionell ist, um **dadurch** eine Öffnungsbewegung der Ventilnadel (134) zu verursachen,
wobei die erste Aktoranordnung (150) einen elektromagnetischen Aktor mit einem ersten Anker (168), der in Bezug auf die Ventilnadel (134) verschiebbar ist, und ein erstes Kernelement (154) umfasst, das so angeordnet ist, dass sich der erste Anker (168) bei Betätigung der ersten Aktoranordnung (150) in Richtung auf das erste Kernelement (154) bewegt,
und wobei die Ventilnadel (134) ein Kopplungselement (192) trägt, das zum Abkoppeln vom ersten Anker (168) als Reaktion auf die genannte Öffnungsbewegung der Ventilnadel (134) angeordnet ist,

dadurch gekennzeichnet, dass das Kopplungselement (192) und der erste Anker (168) durch einen Zwischenraum (224) getrennt sind, wenn die Ventilnadel (134) mit der Sitzregion (137) in Eingriff ist, so dass das Kopplungselement (192) und der erste Anker (168) so angeordnet sind, dass sie als Reaktion auf die Betätigung der ersten Aktoranordnung (150) miteinander gekoppelt werden, um **dadurch** bei Bewegung des ersten Ankers (168) in Richtung auf das erste Kernelement (154) die genannte Öffnungsbewegung der Ventilnadel (134) zu verursachen.

2. Kraftstoffeinspritzvorrichtung nach Anspruch 1, wobei die erste Aktoranordnung (150) funktionell ist, um das anfängliche Heben der Ventilnadel (134) zu verursachen und sich dann als Reaktion auf die genannte Öffnungsbewegung von der Ventilnadel (134) abzukoppeln, und die zweite Aktoranordnung (152) funktionell ist, um die genannte anfängliche Bewegung zu unterstützen und dann die Ventilnadel (134) auf eine Vollhubposition zu transportieren.

3. Kraftstoffeinspritzvorrichtung nach Anspruch 1 oder Anspruch 2, wobei die erste und die zweite Aktoranordnung (150, 152) zum Anwenden einer Öffnungskraft auf die Ventilnadel (134) funktionell sind, um **dadurch** eine Öffnungsbewegung der Ventilnadel (134) zu verursachen.

4. Kraftstoffeinspritzvorrichtung nach einem der vorhergehenden Ansprüche, wobei der erste Anker (168) eine Lagerhülse (174) aufweist, die eine Innenbohrung hat, wobei die Oberfläche der Innenbohrung mit der Ventilnadel (134) in Gleitkontakt ist.

5. Kraftstoffeinspritzvorrichtung nach einem der vorhergehenden Ansprüche, die einen Hubanschlag (196) aufweist, der zur Begrenzung der Bewegung des ersten Ankers (168) in Richtung auf das erste Kernelement (154) angeordnet ist, um das Abkoppeln des ersten Ankers (168) von der Ventilnadel (134) bei ihrer Öffnungsbewegung zu verursachen.

6. Kraftstoffeinspritzvorrichtung nach einem der vorhergehenden Ansprüche, wobei die Ventilnadel (134) einen Druckring (190) und eine Nadelvorspanneinrichtung (186) hat, die auf den Druckring (190) wirkt, um die Ventilnadel (134) in Eingriff mit der Sitzregion (137) vorzuspannen.

7. Kraftstoffeinspritzvorrichtung nach Anspruch 6, die ferner eine Ankervorspanneinrichtung (194) zum Vorspannen des ersten Ankers (168) vom Druckring (190) weg beinhaltet.

8. Kraftstoffeinspritzvorrichtung nach einem der vorhergehenden Ansprüche, wobei die zweite Aktoranordnung (152) einen elektromagnetischen Aktor mit einem zweiten Anker (214) und einem zweiten Kernelement (202) umfasst, die so angeordnet sind, dass der zweite Anker (214) sich bei Betätigung der zweiten Aktoranordnung (152) in Richtung auf das zweite Kernelement (154) bewegt, und wobei der zweite Anker (214) in Bezug auf die Ventilnadel (134) befestigt ist.

9. Kraftstoffeinspritzvorrichtung nach einem der vorhergehenden Ansprüche, wobei die Ventilnadel (134) axial durch die erste Aktoranordnung (150) verläuft, um mit der zweiten Aktoranordnung (152) zusammenzuwirken.

10. Kraftstoffeinspritzvorrichtung nach einem der vorhergehenden Ansprüche, die ein Abstandsmittel (162) zum Beabstanden der ersten Aktoranordnung (150) vom Düsenkörper (120) und/oder ein Abstandsmittel (210) zum Beabstanden der zweiten Aktoranordnung (152) von der ersten Aktoranordnung (150) aufweist.

11. Kraftstoffeinspritzvorrichtung nach einem der vorhergehenden Ansprüche, die eine oder mehrere weitere Aktoranordnungen aufweist.

Revendications

1. Injecteur de carburant (100) à utiliser dans un moteur à combustion interne, l'injecteur de carburant (100) comprenant :

une buse d'injection ayant un corps de buse (120) doté d'un perçage de buse (130) ;

un pointeau de valve (134) qui est reçu dans le perçage de buse (130) et qui peut être engagé avec une région de siège (137) pour commander la distribution de carburant via au moins une sortie de buse (126) ; et

un premier et un second agencement actionneur (150, 152), le premier agencement actionneur (150, 152) au moins ayant pour fonction d'appliquer une force d'ouverture sur le pointeau de valve (134) et provoquer ainsi un mouvement d'ouverture du pointeau de valve (134) ;

dans lequel le premier agencement actionneur (150) comprend un actionneur à solénoïde ayant une première armature (168) qui est capable de coulisser par rapport au pointeau de valve (134), et un premier élément de noyau (154), agencé de telle façon que la première armature (168) se déplace vers le premier élément de noyau (154) lors du fonctionnement du premier agencement actionneur (150) ;

et dans lequel le pointeau de valve (134) porte un élément de couplage (192) qui est agencé pour se découpler de la première armature (168) en réponse audit mouvement d'ouverture du pointeau de valve (134) ;

caractérisé en ce que l'élément de couplage (192) et la première armature (168) sont séparés par un jeu (224) quand le pointeau de valve (134) est engagé avec la région de siège (137), de telle façon que l'élément de couplage (192) et la première armature (168) sont agencés pour s'accoupler l'un à l'autre en réponse au fonctionnement du premier agencement actionneur (150) pour provoquer ainsi ledit mouvement d'ouverture du pointeau de valve (134) lors du mouvement de la première armature (168) vers le premier élément de noyau (154).

2. Injecteur de carburant selon la revendication 1, dans lequel le premier agencement actionneur (150) a pour fonction de provoquer un soulèvement initial du pointeau de valve (134) et de se découpler du pointeau de valve (134) en réponse audit mouvement d'ouverture, et le second agencement actionneur (152) a pour fonction d'assister ledit mouvement initial et d'amener ensuite le pointeau de valve (134) jusqu'à une position totalement levée.

3. Injecteur de carburant selon la revendication 1 ou 2, dans lequel le premier et le second agencement actionneur (150, 152) ont tous les deux pour fonction d'appliquer une force d'ouverture au pointeau de valve (134) pour provoquer ainsi un mouvement d'ouverture du pointeau de valve (134).

4. Injecteur de carburant selon l'une quelconque des revendications précédentes, dans lequel la première armature (168) comprend un manchon porteur (174) ayant un perçage interne, la surface du perçage interne étant en contact de coulissement avec le pointeau de valve (134).

5. Injecteur de carburant selon l'une quelconque des revendications précédentes, comprenant un arrêt de levée (196) agencé pour limiter un mouvement de la première armature (168) vers le premier élément de noyau (154) de manière à provoquer un découplage de la première armature (168) vis-à-vis du pointeau de valve (134) lors d'un mouvement d'ouverture de celui-ci.

6. Injecteur de carburant selon l'une quelconque des revendications précédentes, dans lequel le pointeau de valve (134) inclut un collier de poussée (190), et des moyens de sollicitation de pointeau (186) qui agissent sur le collier de poussée (190) pour solliciter le pointeau de valve (134) en engagement avec la région de siège (137).

7. Injecteur de carburant selon la revendication 6, incluant en outre des moyens de sollicitation d'armature (194) pour solliciter la première armature (167) en éloignement du collier de poussée (190).

8. Injecteur de carburant selon l'une quelconque des revendications précédentes, dans lequel le second agencement actionneur (152) comprend un actionneur à solénoïde ayant une seconde armature (214) et un second élément de noyau (202), agencé de telle façon que la seconde armature (214) se déplace vers le second élément de noyau (154) lors du fonctionnement du second agencement actionneur (152), et dans lequel la seconde armature (214) est fixée par rapport au pointeau de valve (134).

9. Injecteur de carburant selon l'une quelconque des revendications précédentes, dans lequel le pointeau de valve (134) s'étend axialement à travers le premier agencement actionneur (150) pour coopérer avec le second agencement actionneur (152).

10. Injecteur de carburant selon l'une quelconque des revendications précédentes, comprenant des moyens d'espacement (162) pour espacer le premier agencement actionneur (150) depuis le corps de buse (120) et/ou des moyens d'espacement (210) pour espacer le second agencement actionneur (152) depuis le premier agencement actionneur (150).

11. Injecteur de carburant selon l'une quelconque des revendications précédentes, comprenant un ou plusieurs autres agencements actionneurs.

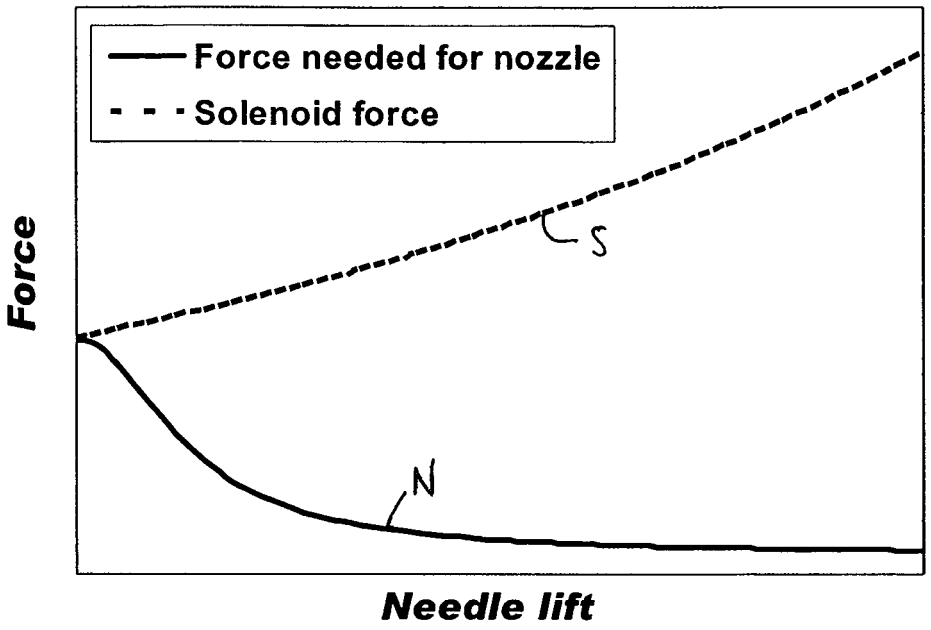

Force needed for nozzle
Solenoid force
S
N
Force
Needle lift

FIGURE 1

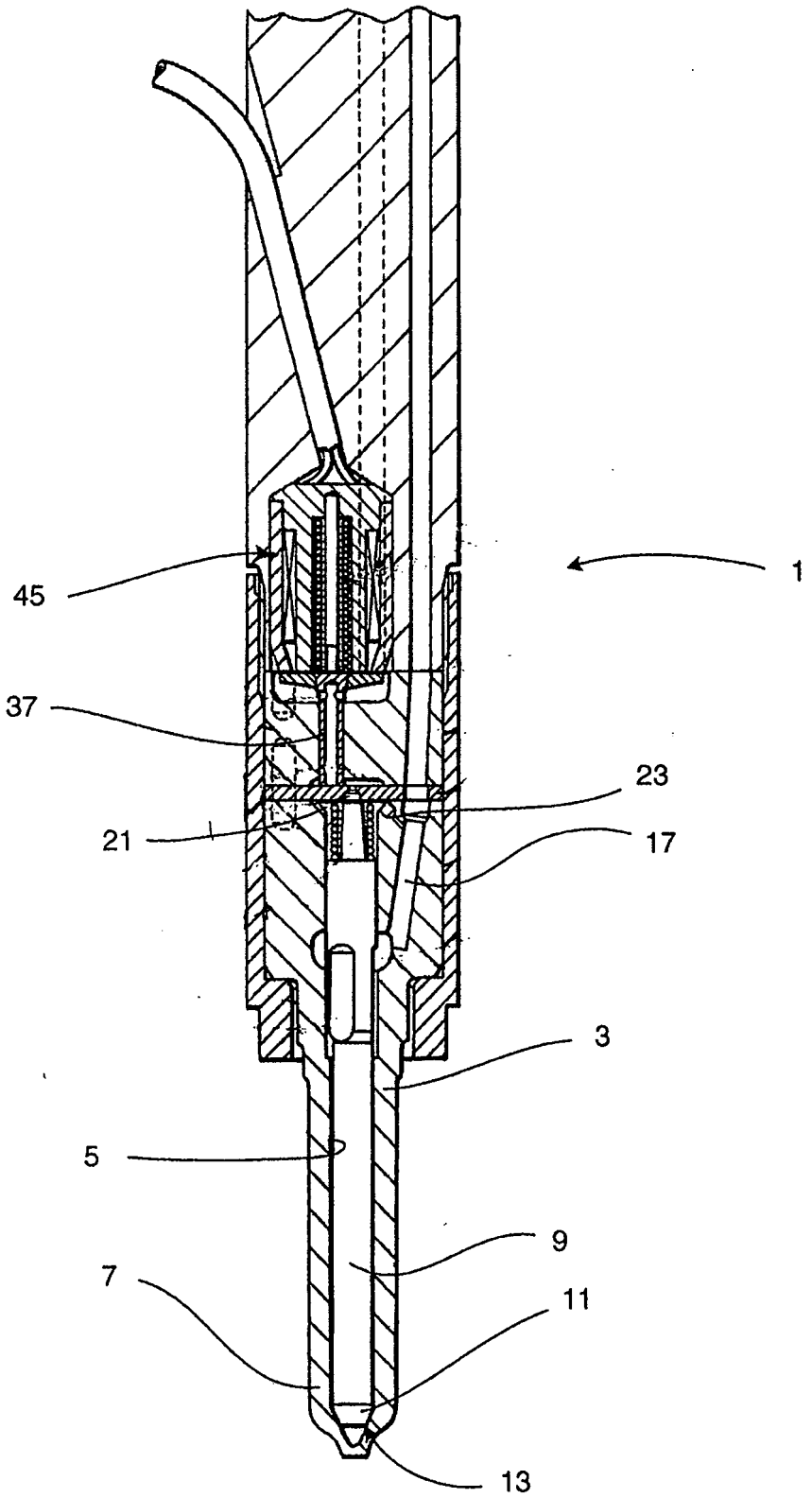


FIGURE 2

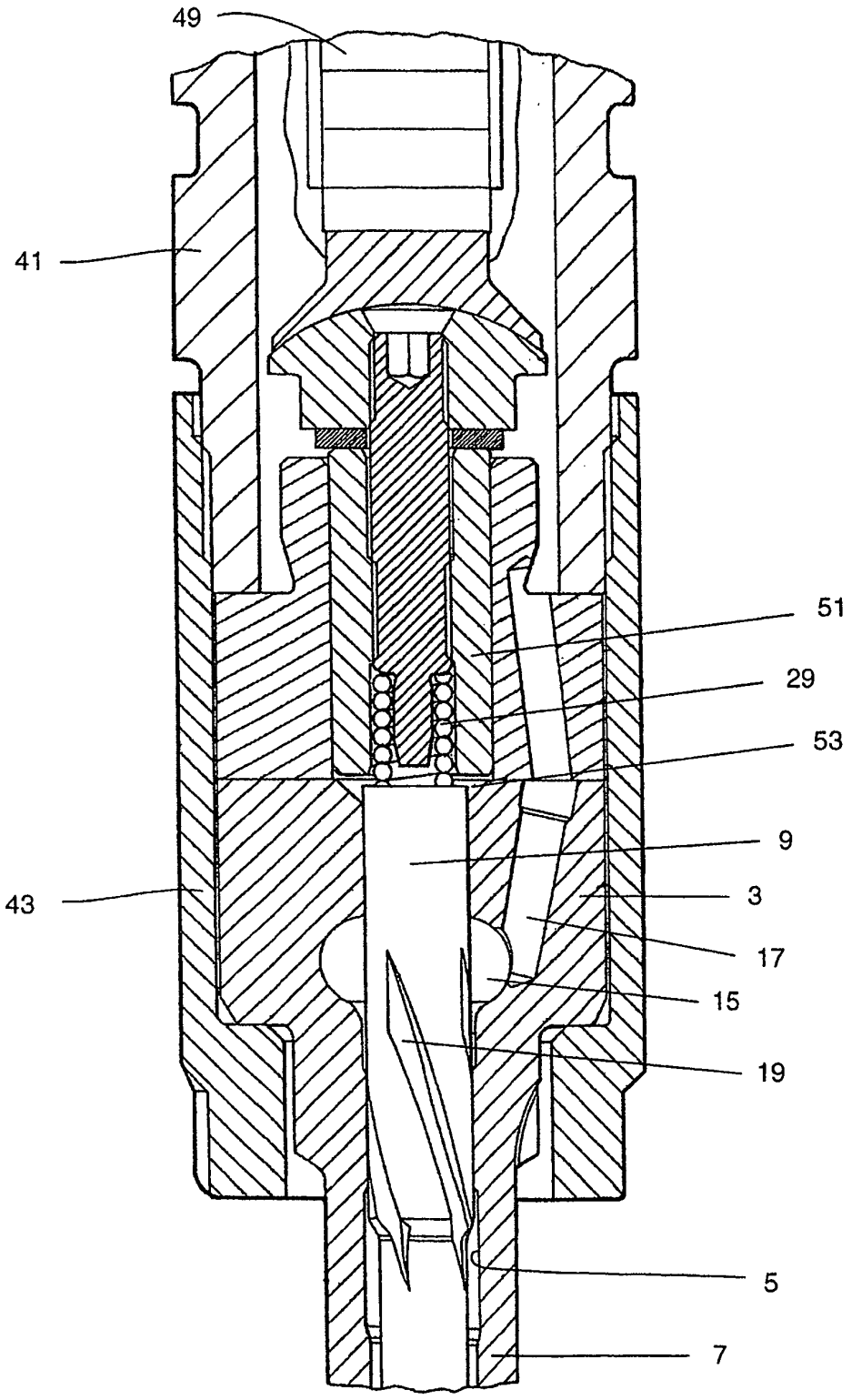


FIGURE 3

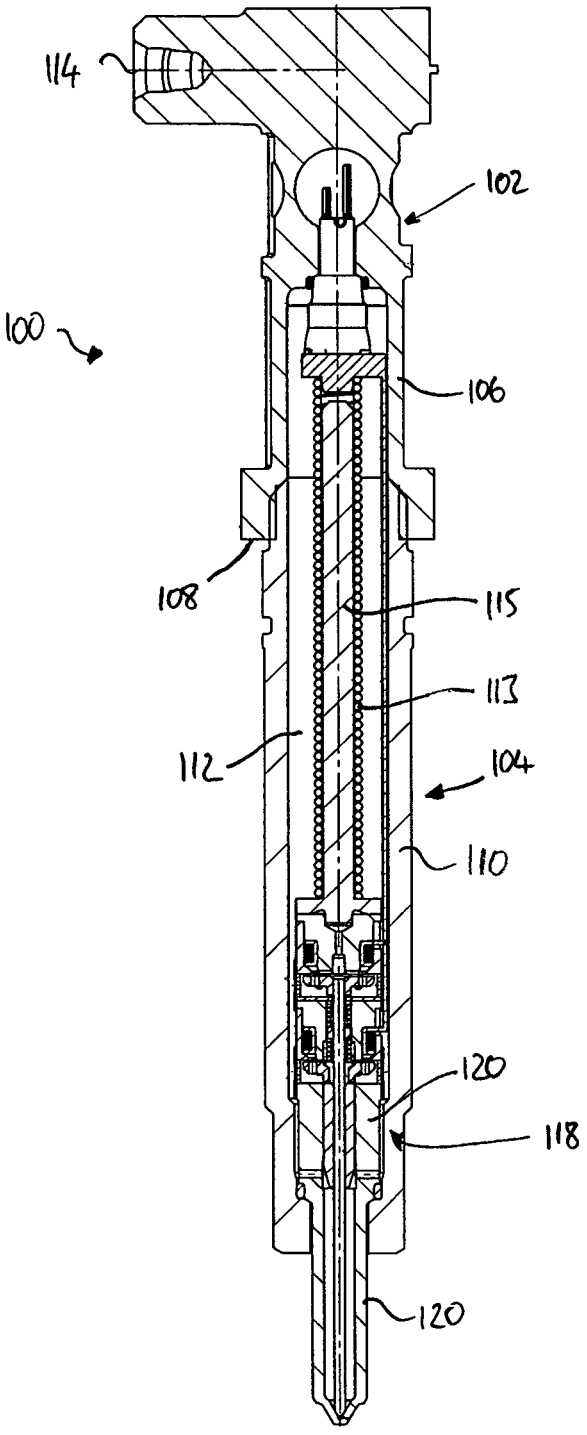


FIGURE 4

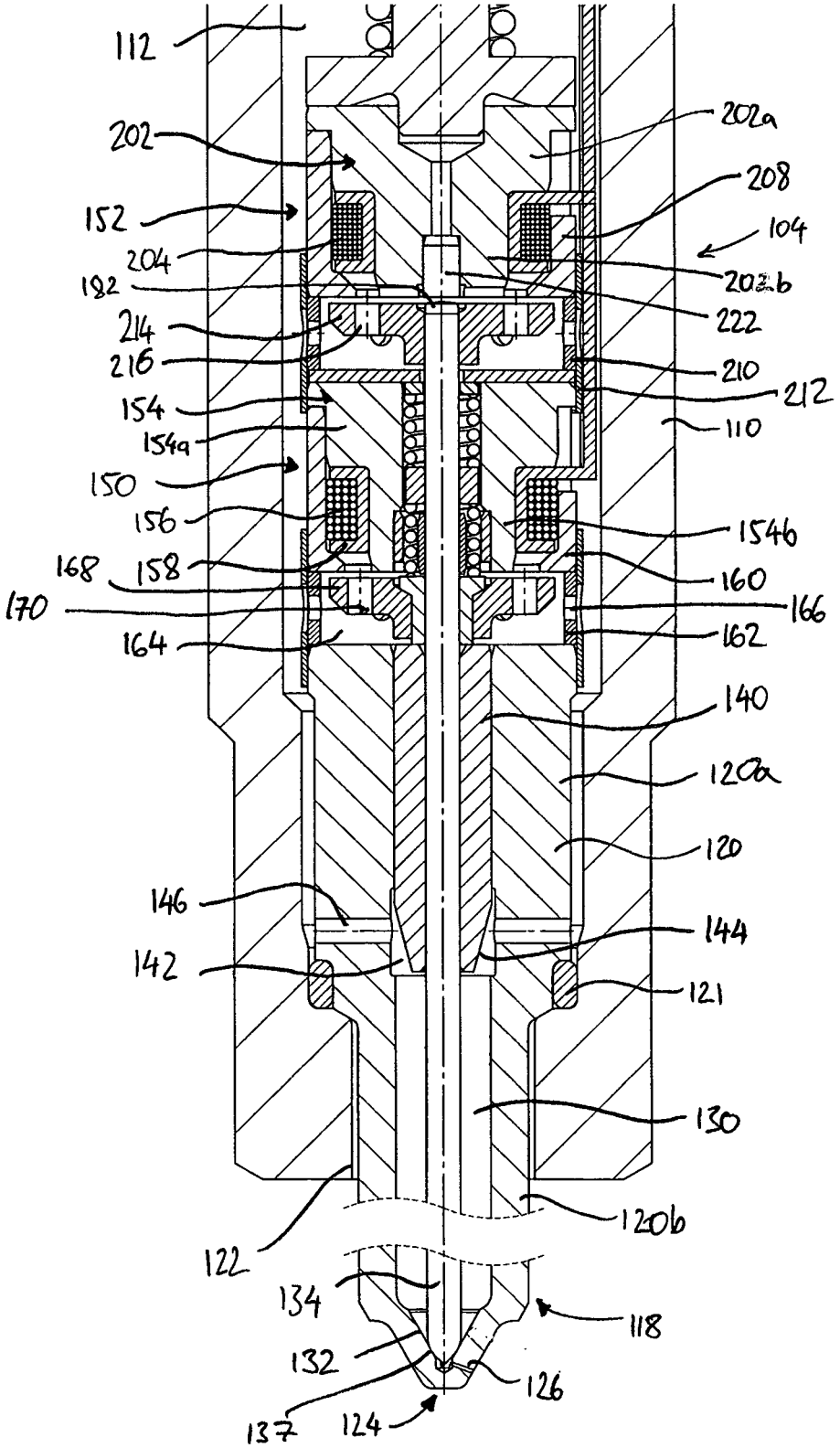

112
202
152
204
182
214
216
154
154a
150
156
168
158
170
164
202a
208
104
202b
222
210
212
110
154b
160
166
162
140
120a
120
146
144
142
121
130
120b
122
134
118
132
126
137
124

FIGURE 5a

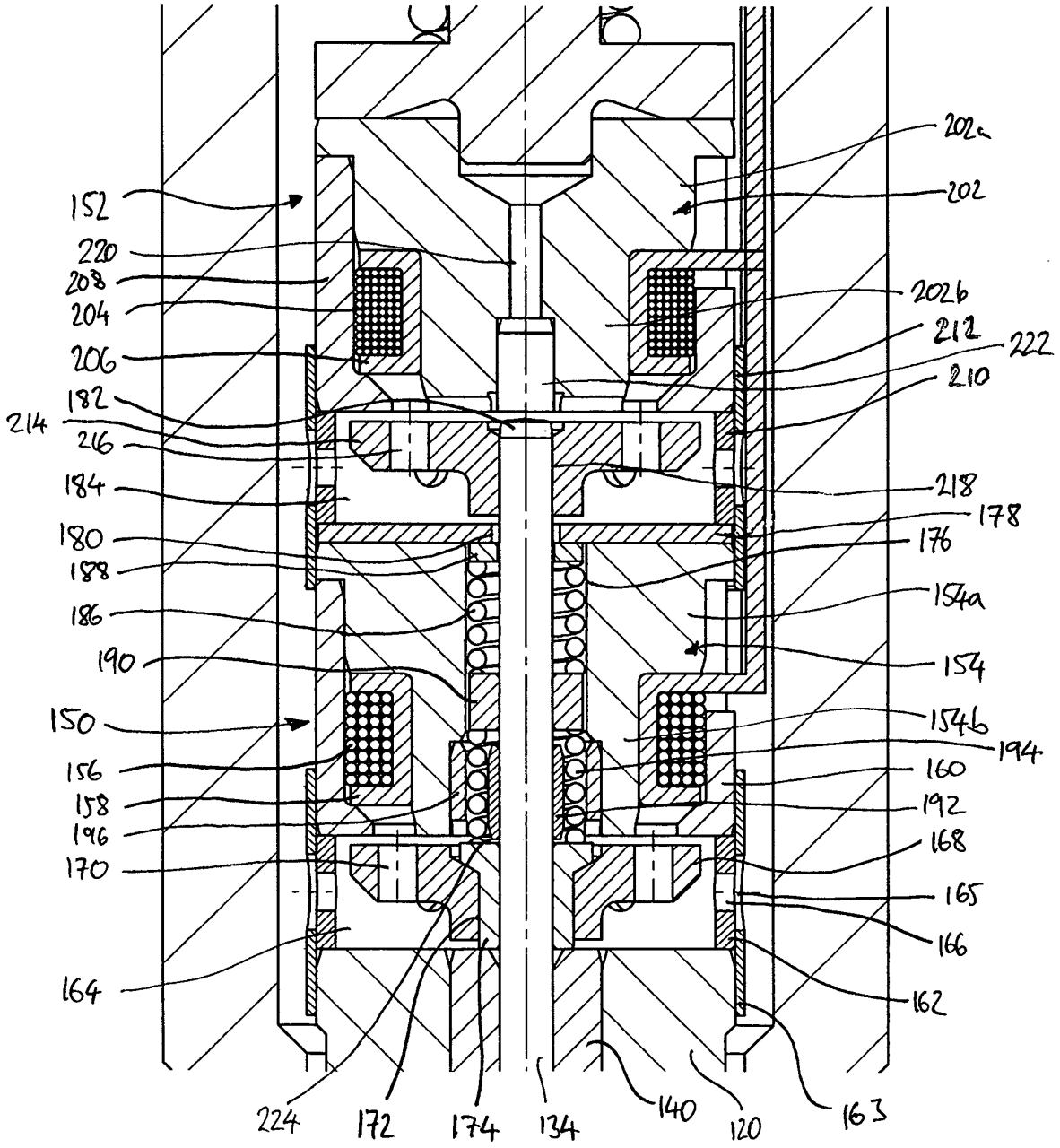

202a
202
152
220
208
204
206
202b
212
222
210
214
182
216
184
218
178
180
176
188
154a
186
154
190
154b
150
194
156
160
158
192
196
168
170
165
166
164
162
224
172
174
134
140
120
163

FIGURE 5b

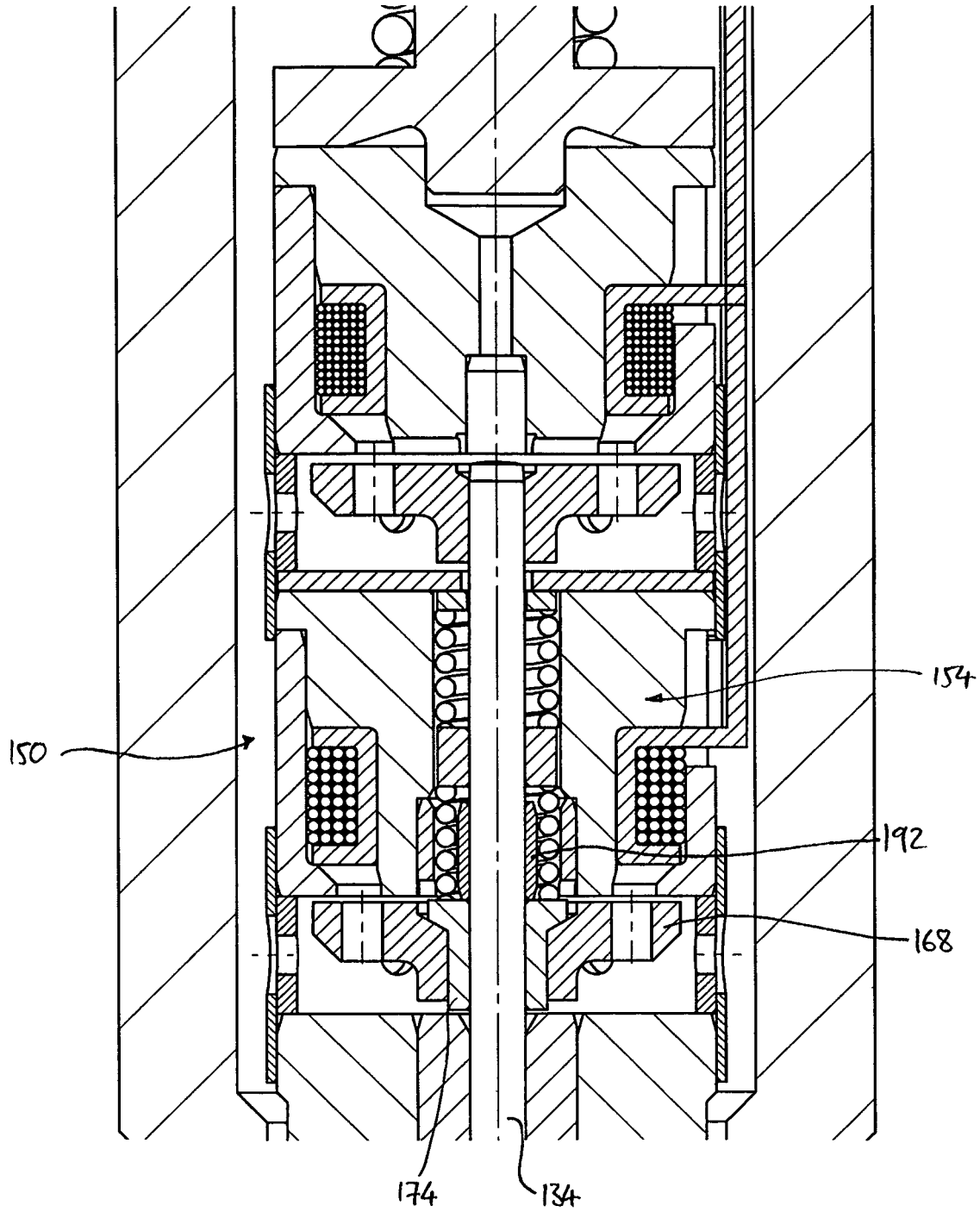


FIGURE 6

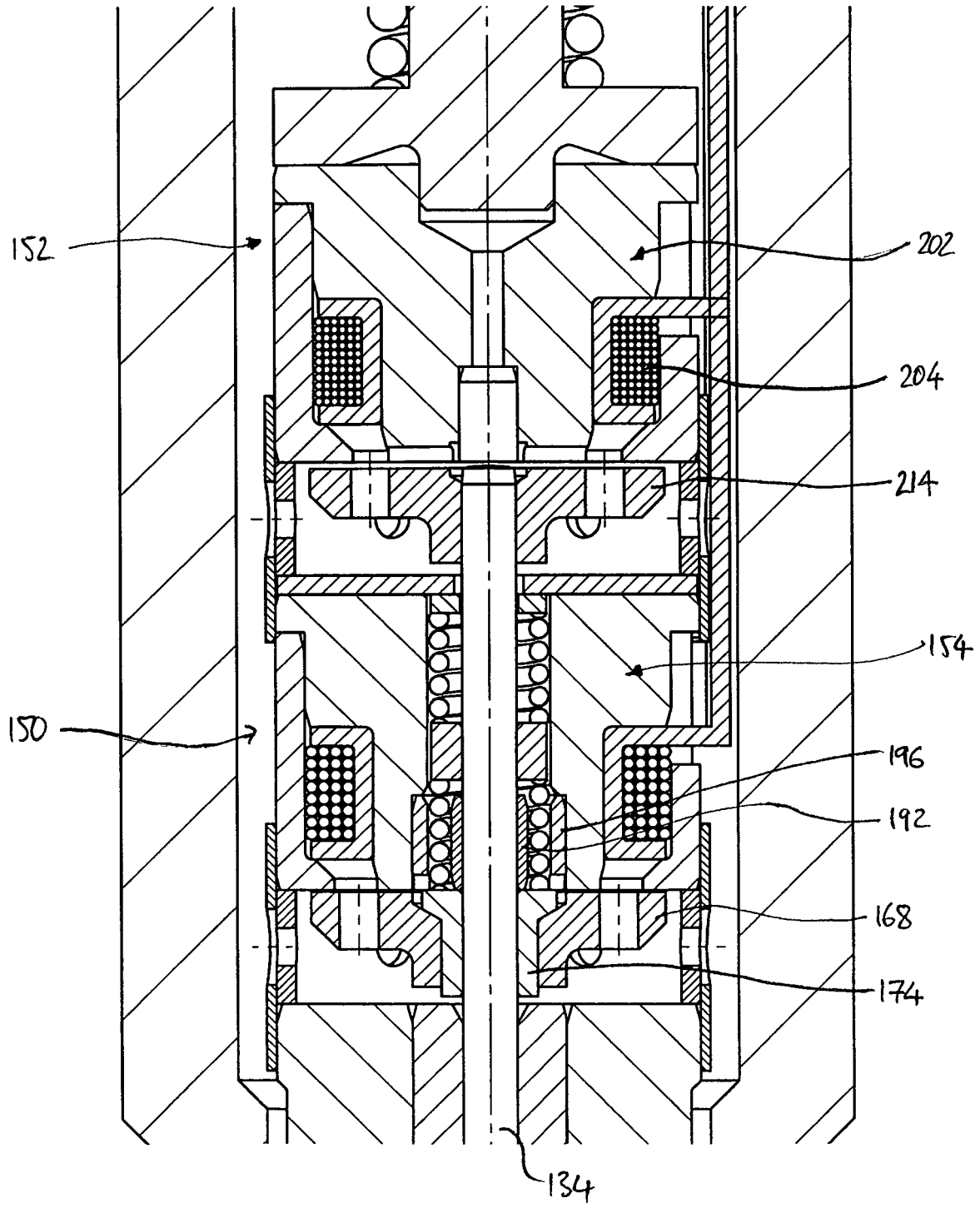


FIGURE 7

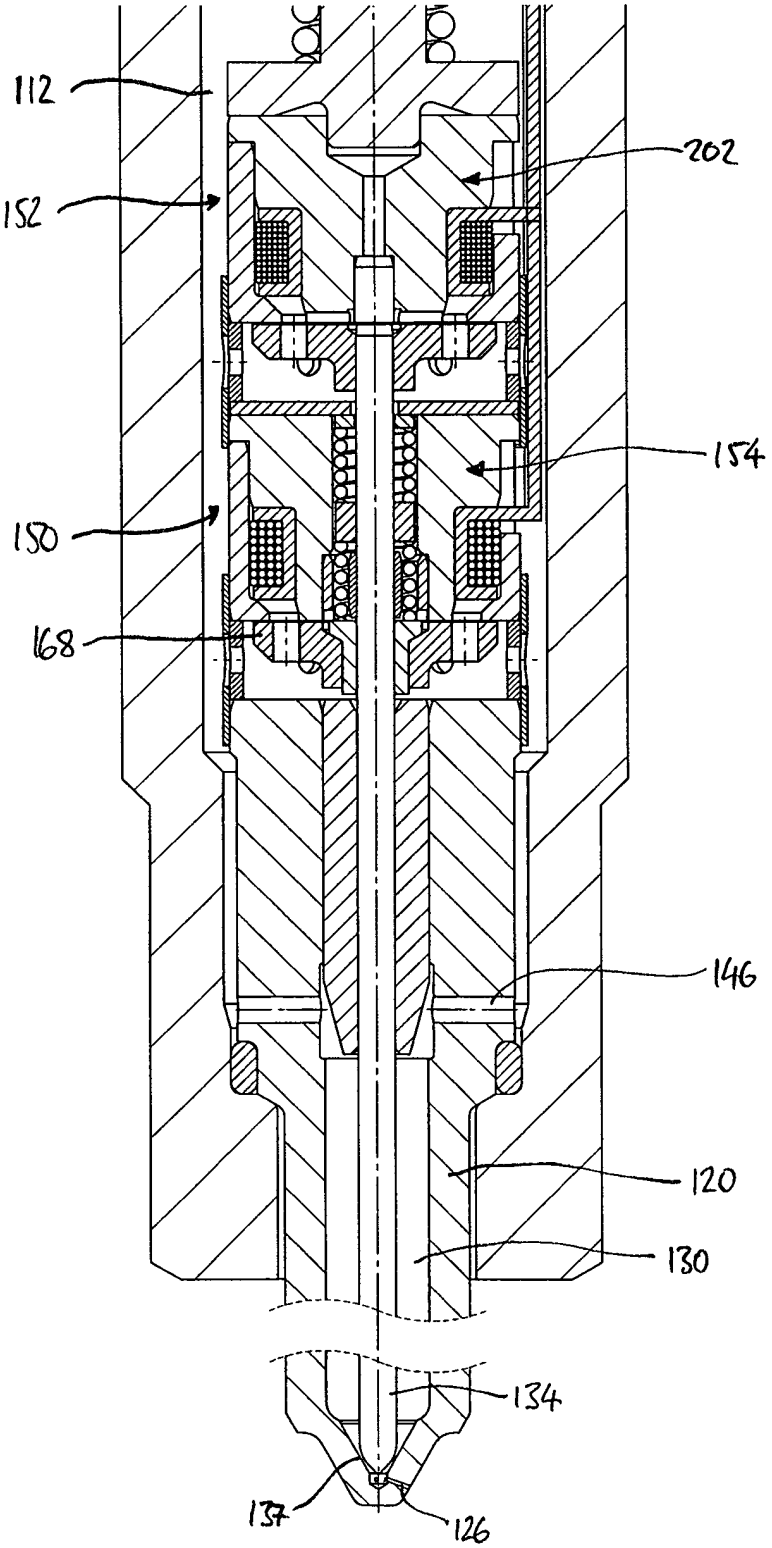


FIGURE 8a

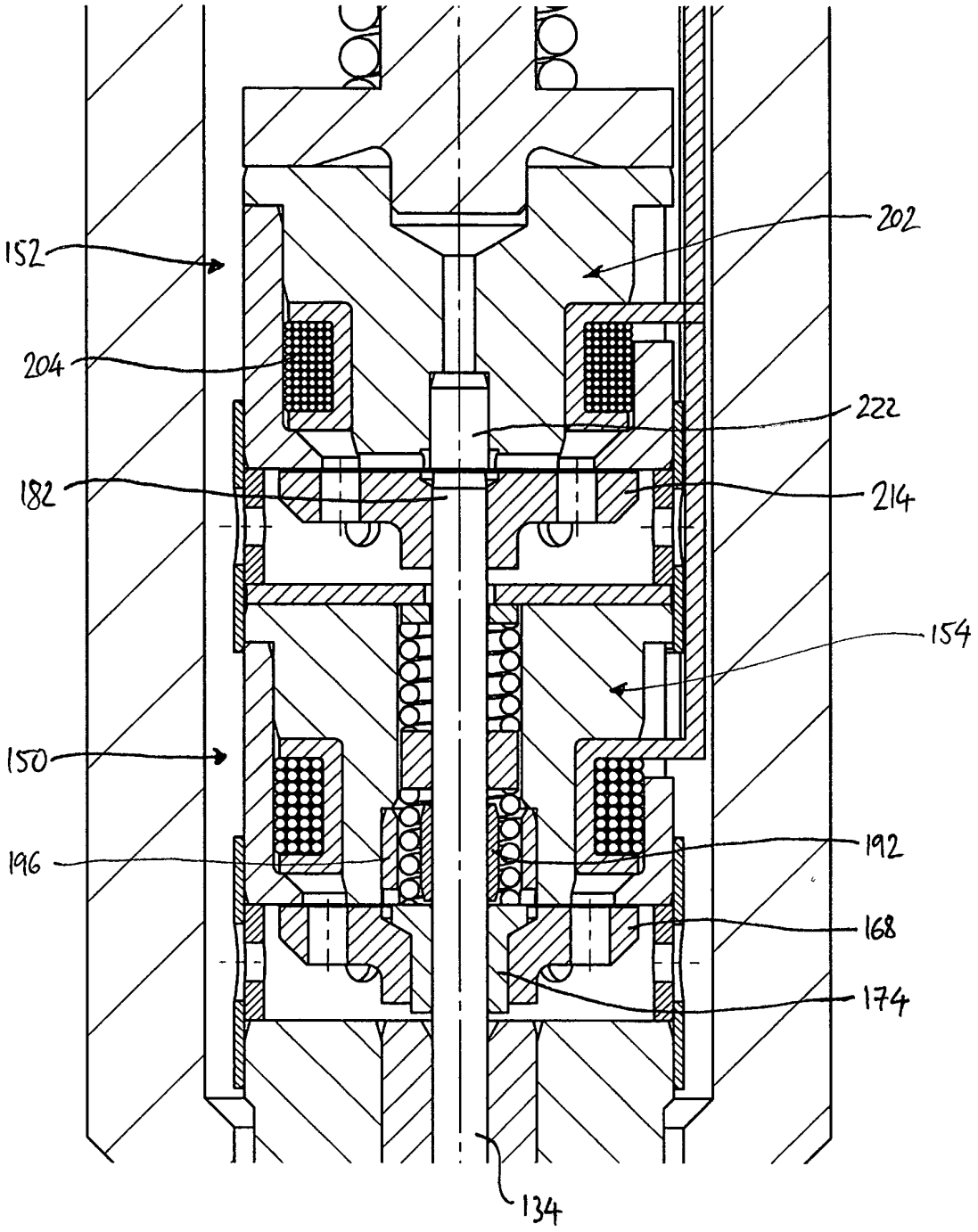


FIGURE 8b

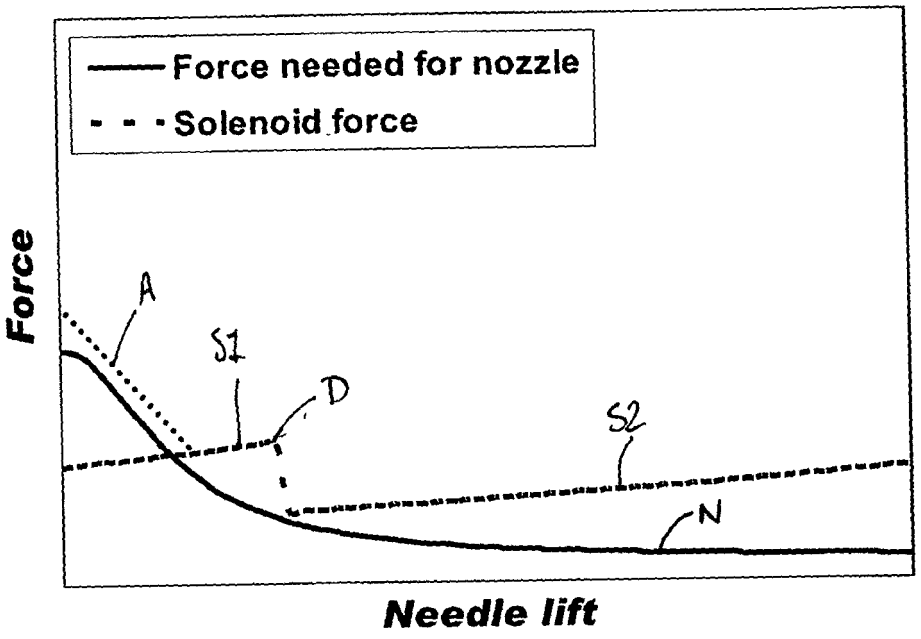

Force needed for nozzle
Solenoid force
Force
A
S1
D
S2
N
Needle lift

FIGURE 9

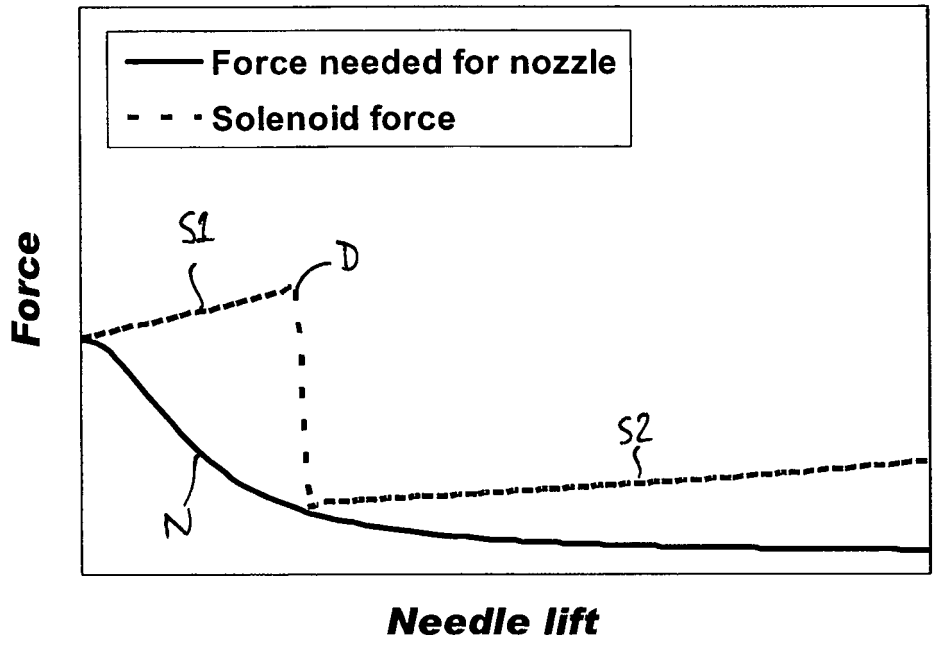

Force needed for nozzle
Solenoid force
S1
D
S2
N
Force
Needle lift

FIGURE 10

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- EP 0647780 A **[0008]**
- EP 0740068 A **[0008] [0009]**
- US 20030116657 A **[0012]**
- WO 03040546 A **[0012]**
- EP 0995901 A **[0013]**
- EP 1174615 A **[0013]**