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(54) **Pumping head**

(57) A pumping head (100; 200) for a high-pressure fuel pump is disclosed. The pumping head comprises a head housing (101; 201) having a bore (106), a pumping element (104) slidably received within the bore (106) and arranged for reciprocal linear movement along a pumping axis (A), a pumping chamber (110) defined in part by the pumping element (104) and in part by the bore (106), wherein a forward stroke of the pumping element (104) causes a reduction in volume of the pumping chamber (110), and a return stroke of the pumping element (104) causes an increase in volume of the pumping chamber (110), inlet means (130; 230) for delivering fluid at relatively low pressure to the pumping chamber (110) during the return stroke. and outlet means (114) for receiving fluid at relatively high pressure from the pumping chamber (110) during the forward stroke and for delivering the relatively high-pressure fluid to an outlet (128) of the pumping head. The pumping element (104) cooperates with the inlet means (130; 230) to restrict the flow of fluid between the inlet means (130; 230) and the pumping chamber (110) during at least a part of the forward stroke so that the inlet means is not exposed to the relatively high-pressure fluid. Preferably, the outlet means (114, 124) is arranged to convey fluid from the pumping chamber (110) to the outlet (128) in a fluid flow direction that is substantially coaxial with the pumping axis (A).

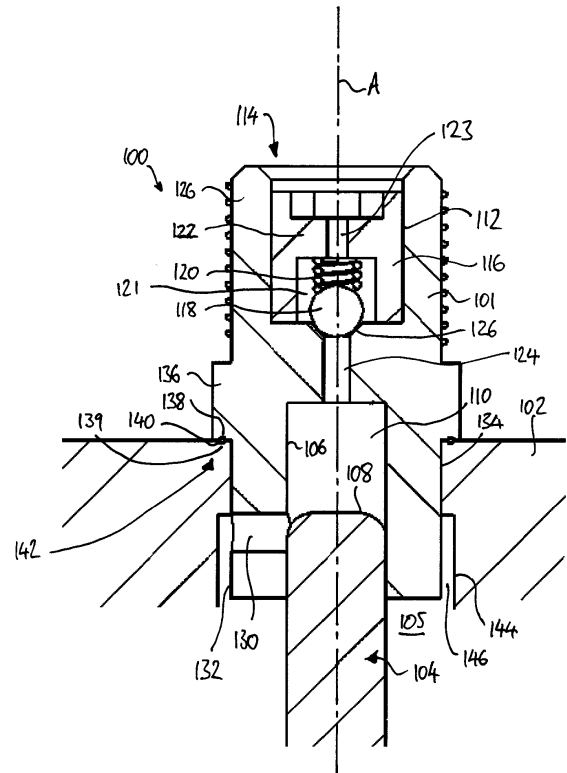


FIGURE 3

Description

Field of the invention

[0001] This invention relates to a pumping head for a fluid pump. In particular, but not exclusively, the invention relates to a pumping head suitable for use in a high-pressure fuel pump of a fuel injection system for an internal combustion engine.

Background to the invention

[0002] Figure 1 of the accompanying drawings is a schematic diagram of a conventional fuel injection system 10 for an internal combustion engine.

[0003] The fuel injection system 10 comprises a plurality of fuel injectors 12. Each injector 12 is arranged to deliver an atomised spray of high-pressure fuel to a respective combustion chamber (not shown) of the engine. The injectors 12 receive fuel at high pressure from an accumulator volume or rail 14, by way of high-pressure supply lines 16. The rail 14 comprises a reservoir for high-pressure fuel.

[0004] Delivery of fuel from the injectors 12 is controlled by an electronic control unit 18. When a fuel injection from one of the injectors 12 is required, the electronic control unit 18 sends an actuation signal to the injector 12, which causes actuation of a delivery valve (not shown) of the injector 12.

[0005] Fuel is pumped to the rail 14 from a storage tank 20 by a fuel pump assembly 22. The fuel pump assembly 22 includes a low-pressure transfer pump 24, which serves to convey fuel from the tank 20 to the pump assembly 22, and a high-pressure pump 26 which elevates the pressure of the fuel to the injection pressure, typically of the order of 2000 bar. Fuel is conveyed from the tank 20 to the pump assembly 22 by way of a low-pressure fuel line 28, and from the pump assembly 22 to the rail by way of a high-pressure fuel line 30.

[0006] An inlet metering valve 32, under the control of the engine control unit 18, is provided between the transfer pump 24 and the high-pressure pump 26 of the pump assembly 22. The inlet metering valve 32 determines how much fuel reaches the high-pressure pump 26, for subsequent pressurisation and delivery to the rail 14. The fuel pressure in the rail 14 is regulated to a target value by the electronic control unit 18. A pressure-limiting valve 36 and return line 38 prevent the rail pressure exceeding a pre-determined acceptable level.

[0007] The high-pressure pump 26 comprises a pumping head 50, shown schematically in Figure 2, which is arranged to receive a reciprocable pumping plunger or pumping element 52. The pump 26 further comprises a drive assembly (not shown) for driving reciprocal movement of the pumping element 52 along a pumping axis Q.

[0008] The pumping head 50 comprises a housing 56 that includes a blind bore 58. The pumping element 52 is slidably received within the bore 58. A pumping cham-

ber 60 at the blind end of the bore 58 is defined in part by the pumping member 52 and in part by the bore 58. As the pumping element 52 is driven in reciprocal linear motion along the pumping axis Q by the drive assembly, the volume of the pumping chamber 60, and hence the pressure in the pumping chamber 60, increases and decreases accordingly.

[0009] The pumping head 50 further comprises a spring-biased inlet valve 62 and a spring-biased outlet valve 64. When the pumping element 52 moves downwards (referred to as a filling stroke or return stroke of the pumping element 52), the volume of the pumping chamber 60 increases, the outlet valve 64 closes, and the inlet valve 62 opens when the pressure differential across it reaches a first predetermined level. Fuel is then admitted to the pumping chamber 60 from a fuel supply port 63, through the inlet valve 62. The fuel supply port 63 is fed with fuel from the inlet metering valve (32 in Figure 1).

[0010] When the pumping element 52 moves upwards (referred to as a pumping stroke or forward stroke of the pumping element 52), the volume of the pumping chamber 60 decreases, the inlet valve closes 62, and the pressure of fuel in the pumping chamber 60 increases. The outlet valve 64 is arranged to open at a second pre-determined pressure. Fuel is then delivered through the outlet valve 64 from the pumping chamber 60 at the second pre-determined pressure, for delivery to the fuel rail 14 through an outlet port 65. By setting the second pre-determined pressure at a high level, for example 2000 bar or more, pressurisation of the fuel rail 14 to the desired level can be achieved.

[0011] The pumping head 50 is generally 'T'-shaped, so that the housing 56 comprises a vertically-extending portion 56a and first and second horizontally-extending portions 56b, 56c that extend in opposite directions from the vertically-extending portion 56a. The bore 58 extends within the vertically-extending portion 56a of the housing 56, and the inlet and outlet valves 62, 64 are received in the first and second horizontally-extending portions 56b, 56c, respectively.

[0012] It is important to avoid leakage of high-pressure fuel from the pumping chamber 60, since fuel leakage can give rise to a significant fire risk. Furthermore, leakage of high-pressure fuel leads to inefficient operation, since the energy used to pressurise the leaked fuel is wasted.

[0013] Accordingly, it is necessary to provide high-pressure fuel seals in the pumping head of Figure 2. As will now be described, a first high-pressure seal 70 is provided to prevent leakage of fuel from the pumping chamber 60 past the inlet valve 62, and a second high-pressure seal 72 is provided to prevent leakage of fuel from the pumping chamber 60 past the outlet valve 64.

[0014] The first horizontally-extending portion 56b of the housing 56 includes an inlet passage 74 that extends laterally from the pumping chamber 60. The inlet passage 74 opens into an enlarged-diameter inlet valve bore 76

that houses the inlet valve 62, so that, when the inlet valve 62 is open, fuel can flow from the supply port 63, through the inlet valve 62 and the inlet passage 74 into the pumping chamber 60. A first internal shoulder 78 of the housing 56 is defined where the relatively large diameter inlet valve bore 76 meets the relatively small diameter inlet passage 74.

[0015] At its outside end, the inlet valve bore 76 includes an internally-threaded region 76a. The inlet valve 62 has an externally-threaded region that engages with the threaded region 76a of the inlet valve bore 76 to secure the inlet valve 62 in the housing 56.

[0016] In use, an end face of the generally cylindrical inlet valve 62 is clamped against the first shoulder 78 of the housing 56 to form the first high-pressure seal 70. The inlet valve 62 can be screwed into the inlet valve bore 76 to a sufficient degree to ensure that no fuel leaks past the first high-pressure seal 70. A sealing washer may also be provided between the inlet valve 62 and the shoulder 78.

[0017] A similar arrangement is present in the second horizontally-extending portion 56c of the housing 56. The outlet valve 86 comprises a generally cylindrical end member 64a, a valve ball 64b, and a spring 64c that acts between the valve ball 64b and the end member 64a.

[0018] In this case, an outlet passage 84 extends laterally from the pumping chamber 60 to open into an enlarged-diameter outlet valve bore 86 that houses the end member 64a of the outlet valve 64. The outlet passage 84 includes a first portion 84a adjacent to the pumping chamber 60, and a second portion 84b with a larger diameter than the first portion 84a. A valve seat 84c for the valve ball 64b is provided in the outlet passage 84, where the first portion 84 meets the second portion 84b.

[0019] When the outlet valve 64 is open (i.e. when the valve ball 64b is lifted off the valve seat 84c), fuel can flow from the pumping chamber 60, through the outlet passage 84 and the outlet valve 64 and out of the housing 56 via the outlet port 65. A second internal shoulder 88 of the housing 56 is defined where the relatively large diameter outlet valve bore 86 meets the relatively small diameter outlet passage 84. At its outside end, the outlet valve bore 86 includes an internally-threaded region 86a that engages with an externally-threaded region of the outlet valve 64 to secure the outlet valve 64 in the housing 56.

[0020] In use, an end face of the generally cylindrical outlet valve 64 is clamped against the second shoulder 88 of the housing 56, with sufficient clamping force being applied to ensure that no fuel leaks past the second high-pressure seal 72. Again, a sealing washer could be used between the outlet valve 64 and the second shoulder 88. A further high-pressure seal (not shown) is required to seal the connection between the outlet port 65 and a fuel line (30 in Figure 1) that connects the head 50 to the fuel rail (14 in Figure 1), in use.

[0021] It will be appreciated that the requirement to provide high-pressure seals 70, 72 adds substantial cost

and complexity to the pumping head 50, particularly in very high-pressure applications, for example at pressures of 2000 bar or more. Furthermore, because the high-pressure seals 70, 72 are subject to high stresses during manufacture and use, they represent a potential source of failure of the pumping head.

[0022] Another consideration in the design of pumping heads used in very high-pressure applications, such as the pumping head 50 of Figure 2, is the high loads that act on the housing 56 due to the pressure of fuel in the pumping chamber 60. In particular, where the inlet passage 74 and the outlet passage 84 intersect with the blind bore 58 to open into the pumping chamber 60, it is necessary to shape the intersections between the passages to avoid sharp edges that could act to cause local stress concentrations and, potentially, failure of the pumping head due to fatigue damage. The shaping of intersections between such passages is described, for example, in the Applicant's International Patent Application Publication No. WO2006/131741.

[0023] The requirement to shape the intersections between the passages, for example by mechanical or electrochemical machining, also adds cost and complexity to the pumping head 50, and in particular to the process for manufacturing such a pumping head.

[0024] Against this background, it would be desirable to provide a pumping head that addresses or overcomes the problems of the prior art.

Summary of the invention

[0025] From a first aspect, the present invention resides in a pumping head for a high-pressure fuel pump, comprising a head housing having a bore, a pumping element slidably received within the bore and arranged for reciprocal linear movement along a pumping axis, and a pumping chamber defined in part by the pumping element and in part by the bore, wherein a forward stroke of the pumping element causes a reduction in volume of the pumping chamber and a return stroke of the pumping element causes an increase in volume of the pumping chamber. The pumping head further comprises inlet means for delivering fluid at relatively low pressure to the pumping chamber during the return stroke, and outlet means for receiving fluid at relatively high pressure from the pumping chamber during the forward stroke and for delivering the relatively high-pressure fluid to an outlet of the pumping head.

[0026] The pumping element cooperates with the inlet means to restrict the flow of fluid between the inlet means and the pumping chamber during at least a part of the forward stroke so that the inlet means is not exposed to the relatively high-pressure fluid.

[0027] During the forward stroke, fluid in the pumping chamber is pressurised as a result of the reduction in volume of the pumping chamber, so that fluid is delivered to the outlet means at high pressure. Advantageously, because the pumping element restricts flow between the

pumping chamber and the inlet means during the forward stroke, the entire inlet means can be substantially isolated from the high fluid pressures that arise in the pumping chamber and, accordingly, the housing is not subjected to high stresses around the inlet means. The likelihood of fatigue damage is therefore reduced.

[0028] It is a further benefit of the invention that a high-pressure seal associated with the inlet means is not necessary. Furthermore, because the inlet means is substantially isolated from the pumping chamber, the effective volume of fluid that is in communication with the pumping chamber during the forward stroke (known as the 'dead volume') is reduced. By reducing the dead volume, and therefore the volume of fluid that must be compressed to achieve a given fluid pressure increase, a more efficient pumping action is achieved.

[0029] The pumping head of the present invention is therefore less complex, more efficient, more reliable and less costly to manufacture than previously-known pumping heads of the type shown in Figure 2.

[0030] The inlet means preferably comprises at least one inlet passage that communicates with the bore. The pumping element may occlude the or each inlet passage to restrict the flow of fluid from the inlet passage to the pumping chamber.

[0031] The outlet means may be arranged to convey fluid from the pumping chamber to the outlet in a fluid flow direction that is substantially coaxial with the pumping axis. Advantageously, in this arrangement, stress concentrations in the pumping head are minimised, and in particular are reduced compared to known arrangement in which fluid is conveyed from a pumping chamber to an outlet in a direction that is, for example, at perpendicular to the pumping axis. In one example, the outlet means comprises a passage that opens into the pumping chamber, and the passage is substantially coaxial with the pumping axis.

[0032] The outlet means may comprise an outlet valve for controlling the flow of fluid from the pumping chamber to the outlet through a fluid flow path substantially parallel to the pumping axis. The outlet valve may comprise a valve body, and the housing may comprise a bore for receiving the valve body. The valve body may be an interference fit in the bore.

[0033] The outlet valve may comprise a valve element, and the valve element may be moveable in a direction that is substantially coaxial with the pumping axis for controlling the flow of fluid from the pumping chamber to the outlet.

[0034] In one advantageous arrangement, the outlet of the pumping head comprises a port that defines the bore for receiving the valve body. In this way, the requirement for a high-pressure seal to seal the valve body in the pumping head can be avoided.

[0035] The fluid flow path may comprise a passage in the valve body. The passage is preferably substantially coaxial with the pumping axis.

[0036] A second aspect of the present invention re-

sides in a high-pressure pump for a fuel injection system, comprising a pumping head according to the first aspect of the invention, a pump body comprising a pump housing defining an internal volume and including an aperture for receiving the pumping head, and a drive mechanism housed in the internal volume and arranged to drive the pumping element in reciprocal linear movement along the pumping axis.

[0037] In one embodiment, the inlet means is in communication with the internal volume. In such a case, the fluid to be pumped may be a lubricating fluid that lubricates the drive mechanism in use. The aperture may define a chamber, and the inlet means may communicate with the internal volume by way of the chamber.

[0038] In another embodiment, the pump housing comprises a supply conduit for delivering fluid to the inlet means. In this way, the fluid to be pumped can be kept separate from the drive mechanism. The pump may comprise sealing means to prevent communication between the inlet means and the internal volume.

[0039] The present invention also extends, in a third aspect, to a fuel injection system comprising a high-pressure pump comprising a pumping head according to the first aspect of the invention, or a high-pressure pump according to the second aspect of the invention. The fuel injection system may include a fluid source, and an inlet metering valve for receiving fluid from the fluid source and for delivering the fluid to the inlet means of the pumping head. The inlet metering valve may be remote from the pumping head.

[0040] From a fourth aspect, the invention resides in a pumping head for a high-pressure fuel pump, comprising a head housing having a bore, a pumping element slidably received within the bore and arranged for reciprocal linear movement along a pumping axis, and a pumping chamber defined in part by the pumping element and in part by the bore, wherein a forward stroke of the pumping element causes a reduction in volume of the pumping chamber and a return stroke of the pumping element causes an increase in volume of the pumping chamber. The pumping head further comprises inlet means for delivering fluid to the pumping chamber during the return stroke, and outlet means for receiving fluid from the pumping chamber during the forward stroke and for delivering fluid to an outlet of the pumping head. The outlet means is arranged to convey fluid from the pumping chamber to the outlet in a fluid flow direction that is substantially coaxial with the pumping axis.

[0041] In such an arrangement, the stress concentrations that arise in the housing, for example at intersections between the pumping chamber and the outlet means, are reduced compared to arrangements in which fluid is conveyed by the outlet means in a fluid flow direction that is not substantially coaxial with the pumping axis.

[0042] Preferably, the outlet is axially aligned with the pumping axis. In this way, the pumping head can be fitted to the pump housing in any angular orientation. Further-

more, this flexibility in angular orientation means that misalignment of the pumping plunger, for example due to manufacturing tolerances, is easier to accommodate.

[0043] A fifth aspect of the invention resides in a pumping head for a high-pressure fuel pump, comprising a head housing having a bore, a pumping element slidably received within the bore and arranged for reciprocal linear movement along a pumping axis, and a pumping chamber defined in part by the pumping element and in part by the bore, wherein a forward stroke of the pumping element causes a reduction in volume of the pumping chamber and a return stroke of the pumping element causes an increase in volume of the pumping chamber. The pumping head further comprises inlet means for delivering fluid to the pumping chamber during the return stroke, an outlet port for connection to a high-pressure fluid line, and an outlet valve comprising an outlet valve body housed within the outlet port. The outlet valve is arranged to control the flow of fluid from the pumping chamber to the outlet port through the outlet valve body during the forward stroke.

[0044] Because fluid exits the head through the outlet valve body, which is received within the outlet port, only one high-pressure seal is needed to seal the outlet valve within the head and to seal the connection between the head and an external fluid line.

[0045] Preferred and/or optional features of each aspect of the invention may also be used, alone or in appropriate combination, with the other aspects of the invention also.

Brief description of the drawings

[0046]

Figure 1 of the accompanying drawings, which has been referred to above, is a schematic diagram of a conventional fuel injection system of an internal combustion engine having a conventional high-pressure fuel pump.

Figure 2, which has also been referred to above, is a schematic cross-sectional view of a pumping head of a conventional high-pressure fuel pump for use in the fuel injection system of Figure 1.

[0047] The present invention will now be described, by way of example only, with reference to the remaining accompanying drawings, in which like reference numerals are used for like features, and in which:

Figure 3 is a cross-sectional view of a pumping head according to the invention; and

Figure 4 is a cross-sectional view of another pumping head according to the invention.

[0048] Throughout this description, terms such as 'up-

per', 'lower' and so on relate to the orientation of the components as shown in the accompanying drawings and are used for ease or reference only. It should be understood that the invention could be used in any suitable orientation.

Detailed description of embodiments of the invention

[0049] A first embodiment of the present invention is illustrated in Figure 3. A pumping head 100 is mounted to a pump housing 102 (shown only in part in Figure 3) of a high-pressure fuel pump, for use in a fuel injection system for an internal combustion engine.

[0050] The pump housing 102 houses a drive mechanism (not shown) for a pumping plunger or pumping element 104. The drive mechanism, which may be of a known type, comprises a cam and follower arrangement that drives the pumping element 104 in reciprocal linear motion along a pumping axis A, in use. The drive mechanism is contained within an internal volume 105 of the pump housing 102.

[0051] The pumping head 100 comprises a head housing 101 of generally tubular form, and is arranged so that the tube axis of the head housing 101 is coaxial with the pumping axis A. The pumping head 100 comprises a pumping bore 106 that extends upwardly from a lower end of the head housing 101, in the orientation shown in Figure 3. The pumping bore 106 slidably receives the pumping element 104, and a pumping chamber 110 is defined in part by an end face 108 of the pumping element 104 and in part by the wall of the pumping bore 106.

[0052] An outlet valve bore 112 extends downwardly into the head housing 101 from its upper end. The outlet valve bore 112 houses an outlet valve 114 having a generally tubular valve body 116 and a spherical valve ball 118. The valve ball 118 is biased away from the valve body 116 by a biasing spring 120, which acts between the ball 118 and an internal collar 122 of the valve body 116. The biasing spring 120 is received in a spring chamber 121 defined in part by the bore of the valve body 116, in part by the collar 122, and in part by the lower end of the outlet valve bore 112. A central passage or opening 123 in the collar 122 provides fluid communication between the spring chamber 121 and the upper end of the head housing 101.

[0053] The pumping chamber 110 communicates with the outlet valve bore 112 by way of a flow passage 124 in the head housing 101 that extends coaxially with the pumping axis A. An upper end of the flow passage 124 is shaped to form a valve seat 126 for the ball 118.

[0054] An upper portion of the head housing 101 comprises a tubular outlet port 128 that defines an outlet of the pumping head 100. The port 128 is externally threaded to accept a connector for a high-pressure fuel line (not shown). In use, the high-pressure fuel line delivers fuel from the pumping head 100 to a fuel rail (not shown) of a fuel injection system. The outlet valve bore 112 is lo-

cated within the port 128.

[0055] Conveniently, the outlet valve body 116 is an interference fit within the outlet valve bore 112. In use, the fluid pressure acting on the upwardly-facing surfaces of the outlet valve body 116 as a result of fluid in the fuel line is similar to the fluid pressure acting on the downwardly-facing surfaces of the outlet valve body 116. It is not therefore necessary to secure the outlet valve body 116 in the outlet valve bore 112 with a high-strength threaded connection or similar, although it will be appreciated that such a securing means could be used if desired.

[0056] When the outlet valve 114 is open, fluid flows past the valve ball 118 and the valve body 116, by way of the opening 123. Pressurised fluid therefore exits the head 100 by way of the outlet valve bore 112, into which the valve body 116 is inserted during manufacture. In this way, the pumping head 100 requires only one high-pressure seal between the outlet port 128 of the head housing 101 and the fuel line (not shown), which serves to seal the outlet valve 114 in the housing as well as to connect the head 100 to the fuel line.

[0057] An inlet passage 130 provides fluid communication between the pumping bore 106 and the outer surface 132 of the head housing 101. In this embodiment, the inlet passage 130 extends radially through the wall of the head housing 101, and is arranged to receive fluid at relatively low pressure from within the internal volume 105 of the pump housing 102. Only one inlet passage 130 is shown in Figure 3, but it will be appreciated that more radial inlet passages could be provided at the same axial position but different radial positions in the head housing 101.

[0058] The head housing 101 is mounted in an aperture 134 in the pump housing 102 and is held in place by suitable retaining means. For example, a lower portion of the head housing 101 may be externally threaded for engagement with an internally-threaded portion of the aperture 134. For clarity, the threaded portions are not shown in Figure 3.

[0059] The head housing 101 includes an external collar 136 that abuts the pump housing 102 around the periphery of the aperture 134, in use. A lower face of the collar 136 and an upper face of the pump housing 102 are provided with annular recesses 138, 139 that together receive a sealing washer 140, such as an 'O' ring. In this way, a fluid seal 142 is formed between the head 100 and the pump housing 102. This seal 142 is subjected only to relatively low fluid pressures in use, so need not be adapted to resist the leakage of high-pressure fluid. The collar 136 may be provided with flats to serve as a fixing nut for the pumping head 100.

[0060] To permit fluid flow between the internal volume 105 of the pump housing 102, a lower part 144 of the aperture 134 is formed with an increased diameter, relative to the remaining part of the aperture 134. A clearance 146 between the increased-diameter part 144 of the aperture and the head housing 101 defines an annu-

lar passage through which fluid can reach the inlet passage 130.

[0061] Fluid to be pumped is delivered to the internal volume 105 of the pump housing 102 from a fluid source, such as a fuel tank, by way of an inlet metering valve (not shown). In this way, the inlet metering valve controls the delivery of fluid to the inlet passage 130.

[0062] In use, the pumping element 104 reciprocates cyclically within the pumping bore 106 to define a pumping cycle comprising a forward or pumping stroke and a return or filling stroke. During the forward stroke of the pumping cycle, the pumping element 104 moves upwards to reduce the volume of the pumping chamber 110. During a return stroke of the pumping cycle, the pumping element 104 moves downwards to increase the volume of the pumping chamber 110. The furthest upward extent of travel of the pumping element 104, reached at the end of the forward stroke, is known as the top dead centre (TDC) position, and the furthest downward extent of travel of the pumping element 104, reached at the end of the return stroke, is known as the bottom dead centre (BDC) position.

[0063] The inlet passage 130 is positioned so that, during a first portion of the pumping cycle, the pumping element 104 occludes the opening of the inlet passage 130 into the pumping bore 106. Accordingly, during this first portion of the pumping cycle, the flow of fluid between the inlet passage 130 and the pumping chamber 110 is prevented or at least substantially restricted. The first portion of the pumping cycle includes the end of the forward stroke and the start of the return stroke, when the pumping element 104 is close to or at TDC.

[0064] During a second portion of the pumping cycle, the position of the pumping element 104 is such the opening of the inlet passage 130 into the pumping bore 106 is not occluded by the pumping element 104. In other words, in this second portion of the pumping cycle, fluid can flow substantially freely between the inlet passage 130 and the pumping chamber 110. The second portion of the pumping cycle includes the end of the return stroke and the start of the forward stroke, when the pumping element is close to or at BDC.

[0065] Operation of the pumping head 100 during a pumping cycle will now be described, from a starting point in which the pumping element 104 is at TDC, the inlet passage 130 is closed, and the outlet valve 114 is closed (i.e. the valve ball 118 is seated on the valve seat 126).

[0066] As the pumping element 104 is driven downwards by the drive mechanism, towards BDC, the volume of the pumping chamber 110 increases. Part-way through the return stroke, the end 108 of the pumping element 104 moves past the opening of the inlet passage 130, so that fluid can flow from the inlet passage into the valve bore 106, and consequently into the pumping chamber 110.

[0067] The volume of the pumping chamber 110 increases until the pumping element 104 reaches BDC. Therefore, the effect of the return stroke is to fill the pump-

ing chamber 110 with fluid from the inlet passage 130.

[0068] Once the pumping element 104 passes BDC, the forward stroke of the pumping cycle begins, and the pumping element 104 moves upwards to decrease the volume of the pumping chamber 110. Part-way through the forward stroke, the end 108 of the pumping element 104 passes the inlet passage 130 so that communication between the inlet passage 130 and the pumping chamber 110 is substantially restricted.

[0069] As the forward stroke continues, the pressure of fluid in the pumping chamber 110 increases until the pressure acting on the valve ball 118 is sufficient to overcome the force of the biasing spring 120, allowing the ball 118 to move away from its seat 126. At this point, the outlet valve 114 opens to allow high-pressure fluid to flow from the pumping chamber 110 out of the pumping head 100.

[0070] Once the pumping element 104 reaches TDC, the decrease in volume of the pumping chamber 110 ceases, and the inlet valve 114 closes as the return stroke begins again.

[0071] Because the pumping element 104 occludes the inlet passage 130 during the last stages of the forward stroke, when the pressure in the pumping chamber 110 approaches its maximum value, the inlet passage 130 is isolated or protected from the highest pressures that occur within the pumping head 100. Advantageously, therefore, stress concentrations that arise at the intersection between the inlet passage 130 and the pumping bore 106 are unlikely to give rise to failure of the pumping head 100.

[0072] It is to be noted that all of the flow passages associated with the inflow of relatively low pressure fluid to the pumping chamber 110, including the inlet passage 130 and referred to as the inlet means, are protected from the relatively high fluid pressures that arise in the pumping chamber 110 during the forward stroke. Only the flow passages that are used to convey fluid from the pumping chamber 110 to the outlet of the pumping head 100 (i.e. the flow passage 124, the spring chamber 121 and the opening 123 in the valve body collar 122, together referred to as the outlet means) are exposed to the high-pressure fuel.

[0073] It will be appreciated that the advantage of the invention arises when the inlet passage 130 is protected from the pressure in the pumping chamber 110 during the period immediately before and while the outlet valve 114 is open, as the pumping element 104 approaches TDC. It is therefore preferable that the first portion of the pumping cycle, in which the inlet passage 130 is occluded by the pumping element 104, is a majority portion of the pumping cycle.

[0074] Preferably, the inlet passage 130 is occluded by the valve element 104 over a period of the pumping cycle from approximately 140 degrees before TDC to approximately 140 degrees after TDC.

[0075] Because the pumping element 104 is a sliding fit in the pumping bore 106, a leakage flow of fluid is likely

to be present between the pumping element 104 and the pumping bore 106. Accordingly, when the pumping element 104 occludes the inlet passage 130, flow between the pumping chamber 110 and the inlet passage 130 is not expected to be completely stopped. Instead, a small leakage flow may still be present. However, the benefit of the invention still arises because, when the inlet passage 130 is occluded, the pressure drop between the pumping chamber 110 and the inlet passage 130 is substantial.

[0076] At the start of the return stroke, the outlet valve 114 closes and the inlet passage 130 is still occluded by the pumping element 104. The initial increase in volume in the pumping chamber 110 that occurs before the inlet passage 130 opens results in a partial vacuum being drawn in the pumping chamber 110. When the pumping element 104 clears the inlet passage 130, so that the inlet passage 130 opens, fluid can then flow into the pumping chamber 110 from the inlet passage 130 to relieve the partial vacuum.

[0077] It will be appreciated from Figure 3 that, during the forward stroke, high-pressure fluid flows from the pumping chamber 110 out of the head housing 101 and into the high-pressure fuel line (not shown) along a direction that is coaxial with the pumping axis A.

[0078] In particular, the outlet valve bore 112, the flow passage 124 between the pumping chamber 110 and the outlet valve bore 112, the axis along which the valve ball 118 moves as it disengages and reengages with its seat 126, and the opening 123 in the collar 122 are all aligned with the pumping axis A. Advantageously, this configuration means that the pumping head 100 is relatively simple to manufacture. Furthermore, because the passages in the pumping head 100 that are subject to the highest pressures during operation, such as the pumping bore 110 and flow passage 124, are axially aligned, the stresses at the intersections between the passages are lower than would be the case if the axes of the high-pressure passages intersected at a right angle (as is the case in the prior art pumping head shown in Figure 2).

[0079] The pumping head 100 of the first embodiment of the invention is particularly suitable for use in diesel fuel injection systems, in which the fluid to be pumped is diesel fuel. The diesel fuel has lubricating properties, and therefore the fuel conveniently lubricates the drive mechanism for the pumping element 104 as the fuel flows through the internal volume 105 of the pump housing 102 before it enters the supply passage 130 of the pumping head 100.

[0080] A second embodiment of the invention will now be described with reference to Figure 4, which shows a pumping head 200 mounted to a pump housing 202 of a high-pressure fuel pump. The pumping head 200 of this second embodiment of the invention is similar in most respects to the pumping head 100 of the first embodiment of the invention, and accordingly only the differences between the embodiments will be described in detail. It

should be noted that reference numerals used in Figure 4 that are not specifically referred to below relate to features that are substantially the same as the components with like reference numerals already described above with reference to Figure 3.

[0081] The pumping head 200 and pump housing 202 arrangement of Figure 4 differs from the arrangement of Figure 3 in the way in which fluid is supplied to the inlet passage, as will now be explained.

[0082] In the Figure 4 embodiment, the head housing 201 includes inlet passages 230 that extend radially from the plunger bore 106 to the outer surface 232 of the head housing 201. Two inlet passages 230 are shown in Figure 4, but it will be appreciated that fewer or more radial inlet passages could be provided at the same axial position but different radial positions in the head housing 201. Fluid is supplied to the inlet passages 230 in this case not from the pump housing volume 105, but from a supply conduit 250 provided in the pump housing 202.

[0083] As in the first embodiment of the invention, the pumping head 200 is received in an aperture 234 in the pump housing 202. In this second embodiment, however, the aperture 234 has a substantially uniform diameter through the wall of the pump housing, and the supply conduit 250 opens on to the internal surface 235 of the aperture 234.

[0084] The axial position of the supply conduit 250 corresponds to the axial location of the inlet passages 230, when the head 200 is mounted in the pump housing 202. An annular channel 252 extends around the head housing 201, and the inlet passages 230 and the supply conduit 250 each open into the annular channel 252. Accordingly, fluid is delivered to the pumping bore 106 and hence to the pumping chamber 110 from the supply conduit 250 via the annular channel 252 and the inlet passages 230.

[0085] In this embodiment, first and second sealing grooves 254, 256 extend annularly around the head housing 201 above and below the annular groove 252. 'O' rings or other suitable sealing members (not shown) are received in the sealing grooves 254, 256 to guard against loss of fluid from the supply conduit 250. The corresponding seals are subject only to relatively low fluid pressures, in use.

[0086] A low-pressure seal 142 may also be formed between the collar 136 of the head housing 201 and the pump body 202, as in the first embodiment, in which case the low-pressure seal 142 acts as an additional sealing means for the pump housing 202.

[0087] The pumping head 200 of the second embodiment of the invention is suitable for use in fuel injection systems in which the fluid to be pumped does not lubricate the drive mechanism for the pumping element 104. For example, in gasoline injection systems, a separate lubricating oil may be used to lubricate the drive mechanism, and it is desirable to avoid mixing of the fuel and the lubricating oil.

[0088] Several modifications and variations of the em-

bodiments described above can be contemplated.

[0089] For example, the pumping head may include inlet means that incorporate a conventional inlet valve that delivers fluid to the inlet passage. The inlet valve may be a non-return valve, to prevent the back-flow of fluid from the pumping chamber to the inlet means through the inlet passage.

[0090] The outlet valve may be of a different type to that described above. For example, instead of a ball valve, a needle valve, diaphragm valve or any other suitable valve may be provided. The pumping head may be provided with outlet means in the form of passages without an outlet valve, in which case a suitable non-return valve could be included in the fuel injection system downstream of the pumping head.

[0091] By providing inlet means such as a supply passage that is occluded by the pumping element during the forward stroke in combination with an outlet means arranged so that fluid flows out of the pumping chamber and through the head in a flow direction that is substantially aligned with the pumping axis A, as in the above-described embodiments of the invention, a considerable reduction in the stresses that occur in the pumping head in use can be achieved.

[0092] It will be appreciated, however, that some benefit is obtained from providing an inlet means that is occluded by the pumping element during the forward stroke, in combination with an outlet means having a fluid flow direction that is not aligned with the pumping axis A. For example, the outlet means may be arranged so that high-pressure fluid flows out of the pumping chamber through a passage that intersects with the pumping bore at a 90° angle. In another example, the outlet means may be arranged so that high-pressure fluid flows out of the pumping chamber in a direction having an axis that is offset from and/or at any suitable angle to the pumping axis A. In such cases, although relatively high stresses in the pumping head that are associated with the outlet flow of high-pressure fluid may still arise, depending on the configuration of the outlet means, relatively high stresses are still advantageously avoided in the region of the inlet means.

[0093] Similarly, some benefit can be obtained from providing an outlet means having a fluid flow direction that is aligned with the pumping axis A to minimise the stress concentration in the head housing, in use, even if the inlet means is not occluded by the pumping element during the forward stroke.

[0094] Also, some benefit can be obtained from providing an outlet means comprising an outlet valve located within an outlet port of the housing to avoid the need for a dedicated high-pressure seal to seal the outlet valve in the housing, even if the fluid flow direction in the outlet means is not aligned with the pumping axis A and/or the inlet means is not occluded by the pumping element during the forward stroke.

[0095] It will be appreciated that the pumping head of the present invention is not limited to use in a fuel injection

system, but would be suitable for any application in which a high-pressure pumping head with good reliability and a simple design is desirable.

[0096] Further modifications and variations could also be contemplated by a person skilled in the art, without departing from the scope of the invention as defined in the appended claims.

Claims

1. A pumping head (100; 200) for a high-pressure fuel pump, comprising:

a head housing (101; 201) having a bore (106);
 a pumping element (104) slidably received within the bore (106) and arranged for reciprocal linear movement along a pumping axis (A);
 a pumping chamber (110) defined in part by the pumping element (104) and in part by the bore (106), wherein a forward stroke of the pumping element (104) causes a reduction in volume of the pumping chamber (110), and a return stroke of the pumping element (104) causes an increase in volume of the pumping chamber (110);
 inlet means (130; 230) for delivering fluid at relatively low pressure to the pumping chamber (110) during the return stroke; and
 outlet means (114) for receiving fluid at relatively high pressure from the pumping chamber (110) during the forward stroke and for delivering the relatively high-pressure fluid to an outlet (128) of the pumping head;
 wherein the pumping element (104) cooperates with the inlet means (130; 230) to restrict the flow of fluid between the inlet means (130; 230) and the pumping chamber (110) during at least a part of the forward stroke so that the inlet means is not exposed to the relatively high-pressure fluid.

2. A pumping head according to Claim 1, wherein the inlet means comprises at least one inlet passage (130, 230) that communicates with the bore (106).

3. A pumping head according to Claim 2, wherein the pumping element (104) occludes the or each inlet passage (130; 230) to restrict the flow of fluid from the inlet passage (130; 230) to the pumping chamber (110).

4. A pumping head according to any preceding Claim, wherein the outlet means (114, 124) is arranged to convey fluid from the pumping chamber (110) to the outlet (128) in a fluid flow direction that is substantially coaxial with the pumping axis (A).

5. A pumping head according to Claim 4, wherein the

outlet means comprises a passage (124) that opens into the pumping chamber (110), and wherein the passage (124) is substantially coaxial with the pumping axis (A).

6. A pumping head according to Claim 4 or Claim 5, wherein the outlet means comprises an outlet valve (114) for controlling the flow of fluid from the pumping chamber (110) to the outlet (128) through a fluid flow path (121, 123) substantially parallel to the pumping axis (A).

7. A pumping head according to Claim 6, wherein the outlet valve (114) comprises a valve body (116), and wherein the housing (101) comprises a bore (112) for receiving the valve body (116).

8. A pumping head according to Claim 7, wherein the outlet of the pumping head comprises a port (128) that defines the bore (112) for receiving the valve body (116).

9. A pumping head according to Claim 7 or Claim 8, wherein the fluid flow path comprises a passage (123) in the valve body (116), the passage (123) being substantially coaxial with the pumping axis (A).

10. A high-pressure pump for a fuel injection system, comprising:

a pumping head (100; 200) according to any preceding Claim;
 a pump body comprising a pump housing (102; 202) defining an internal volume (105) and including an aperture (134; 234) for receiving the pumping head (100; 200); and
 a drive mechanism housed in the internal volume (105) and arranged to drive the pumping element (104) in reciprocal linear movement along the pumping axis (A).

11. A pump according to Claim 10, wherein the inlet means (130) is in communication with the internal volume (105).

12. A pump according to Claim 11, wherein the aperture (134) defines a chamber (146), and wherein the inlet means (130) communicates with the internal volume (105) by way of the chamber (146).

13. A pump according to Claim 10, wherein the pump housing (202) comprises a supply conduit (250) for delivering fluid to the inlet means (130).

14. A pump according to Claim 13, comprising sealing means (256) to prevent communication between the inlet means (130) and the internal volume (105).

15. A fuel injection system comprising:

a high-pressure pump comprising a pumping head (100; 200) according to any of Claims 1 to 9, or a high-pressure pump according to any of Claims 10 to 14; 5
a fluid source; and
an inlet metering valve for receiving fluid from the fluid source and for delivering the fluid to the inlet means (130; 230) of the pumping head 10 (100; 200).

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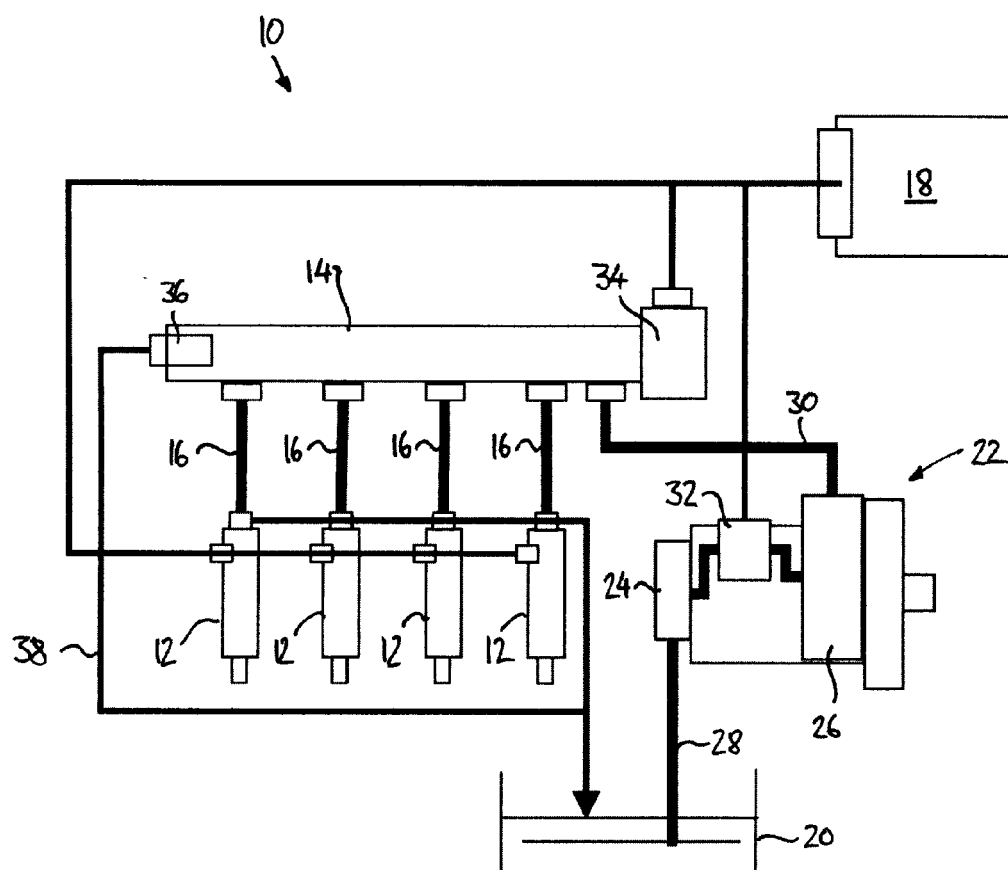


FIGURE 1

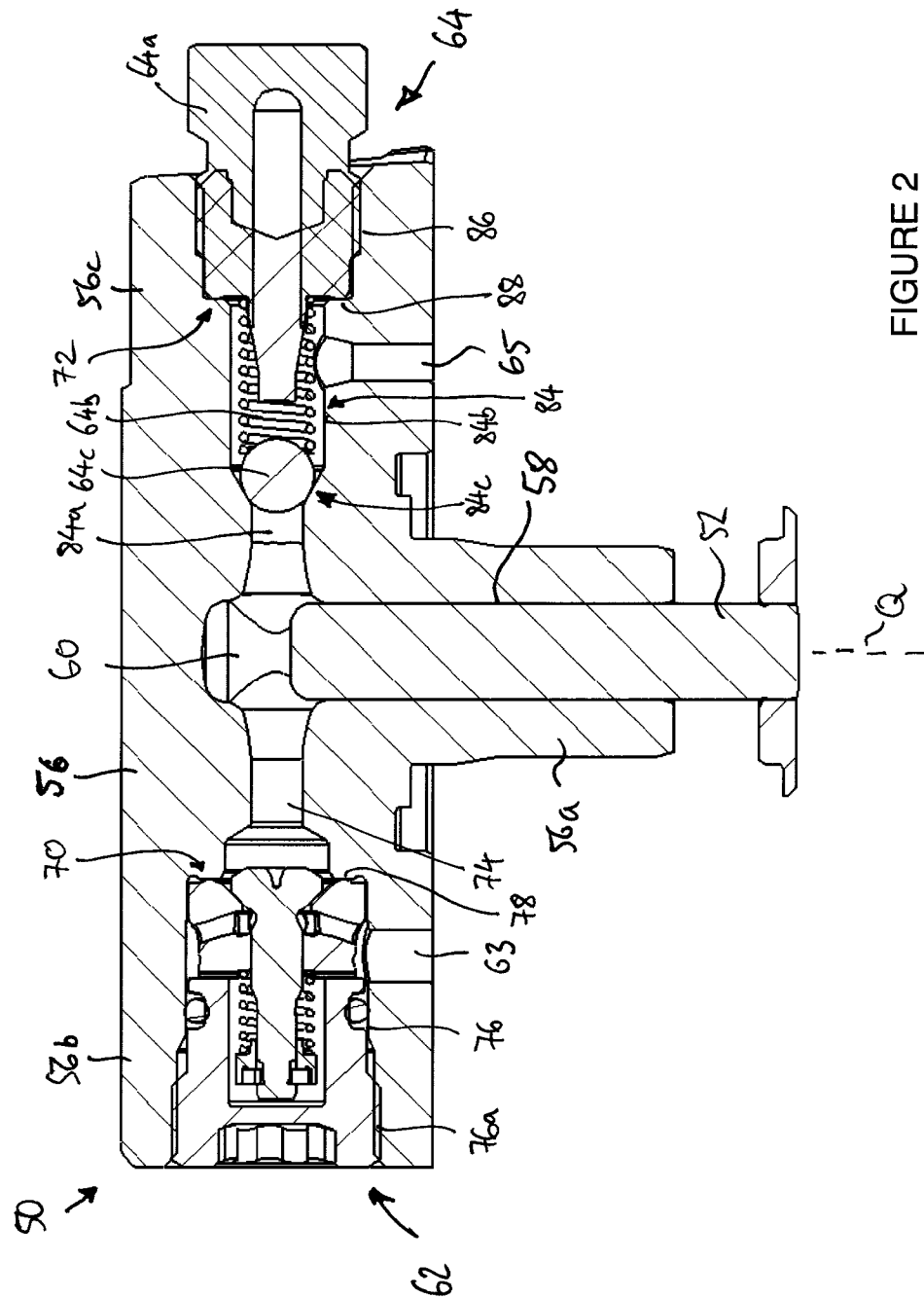


FIGURE 2

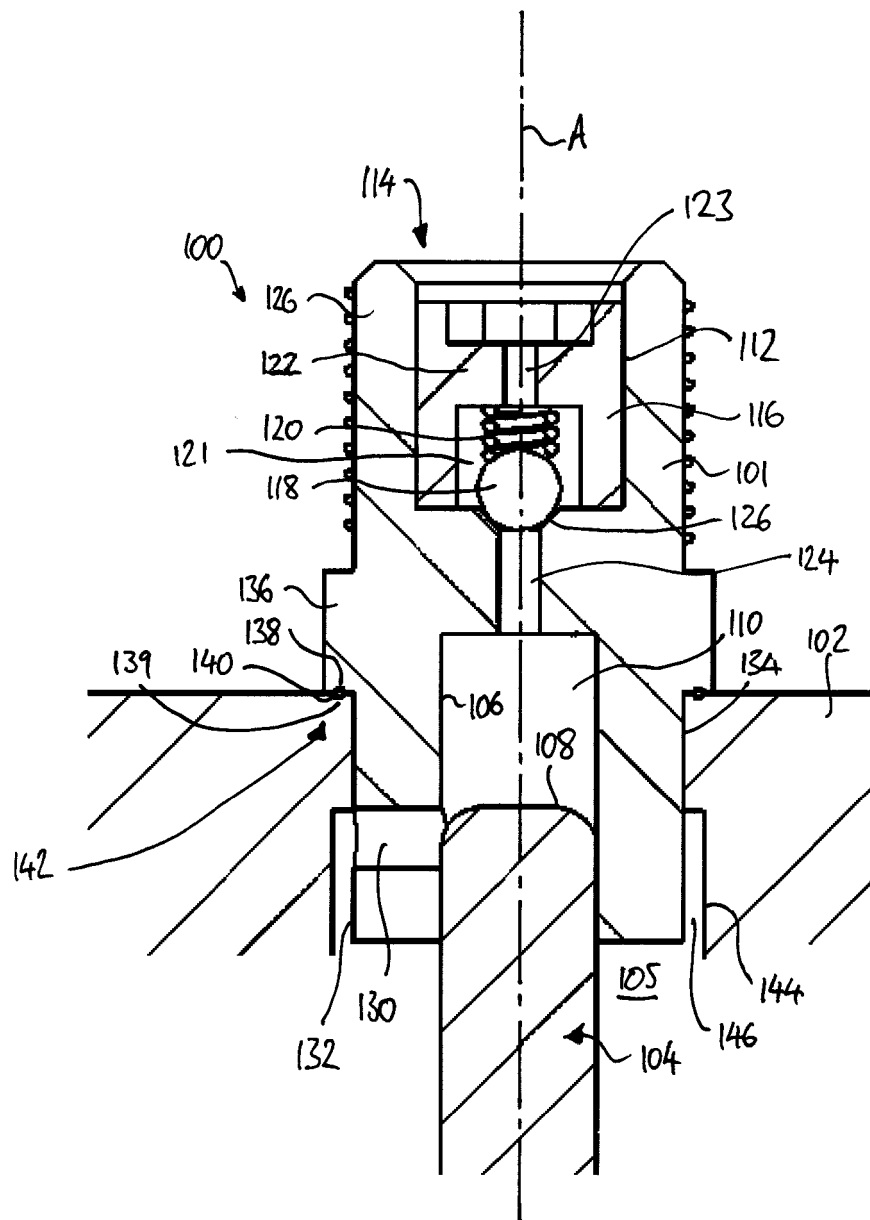


FIGURE 3

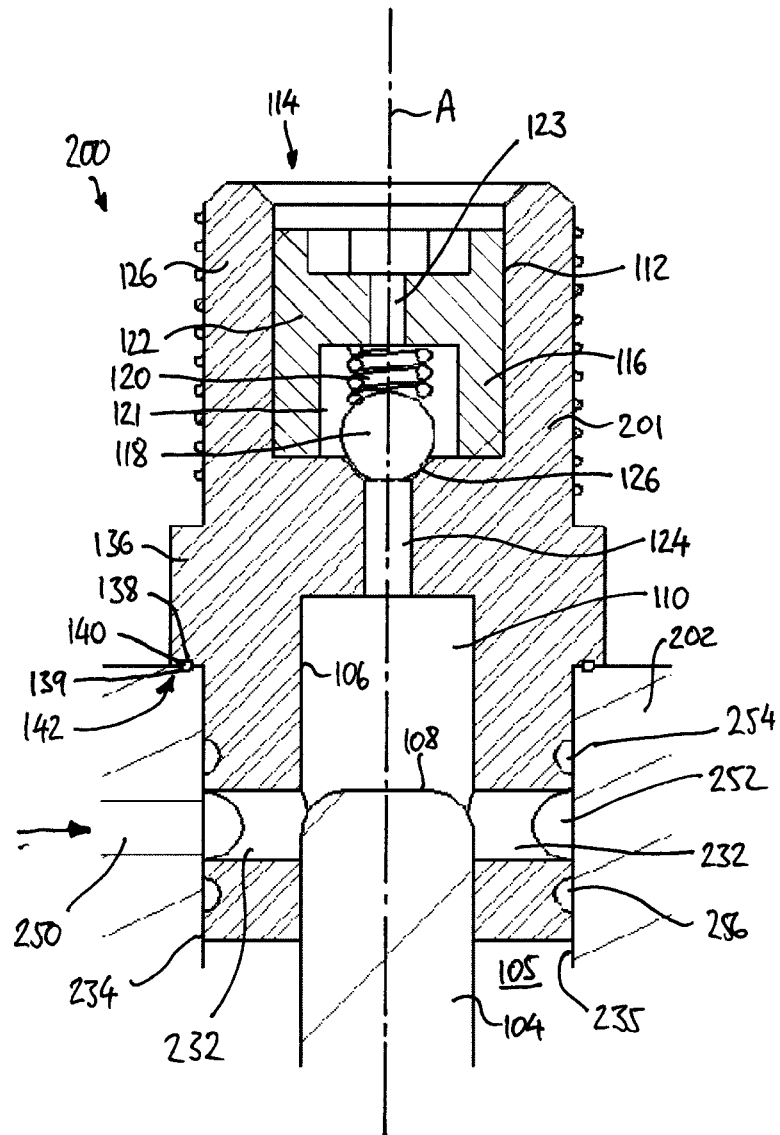


FIGURE 4



EUROPEAN SEARCH REPORT

Application Number
EP 11 15 6276

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Y	* page 2, line 97 - line 112; figure * -----	15	
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The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 5 August 2011	Examiner Schmitter, Thierry
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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EPO FORM 1503 03.82 (P04C01)

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