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(54) **Pumping assembly**

(57) A pumping assembly having a high-pressure pumping stage and an integrated transfer pumping stage. The pumping assembly comprises a cam (104;204) arranged for eccentric rotation about a drive shaft axis (A), a cam rider (106;206), a cam follower (112;212), the cam follower (112;212) having reciprocal movement parallel to a cam follower axis (Q) that is perpendicular to the drive shaft axis (A), a high-pressure pumping head having a high-pressure pumping chamber, and a pumping element driven by the cam follower (112;212). The pumping assembly further comprises a first chamber (150a; 250a), inlet means (174;274) for allowing fluid flow into the first chamber (150a;250a), and outlet means (150b, 163,166,166a;250b,263,266,266a) for receiving fluid from the first chamber (150a;250a) and for delivering fluid to the high-pressure pumping head. Rotation of the cam (104;204) about the driveshaft axis (A) causes an increase in volume of the first chamber (150a;250a) during a first part of the pumping cycle and a decrease in volume of the first chamber (150a;250a) during a second part of the pumping cycle, so as to effect a transfer pumping of fluid from the inlet means (174;274) to the outlet means (150b,163,166,166a;250b,263,266,266a) for delivery to the high-pressure pumping head.

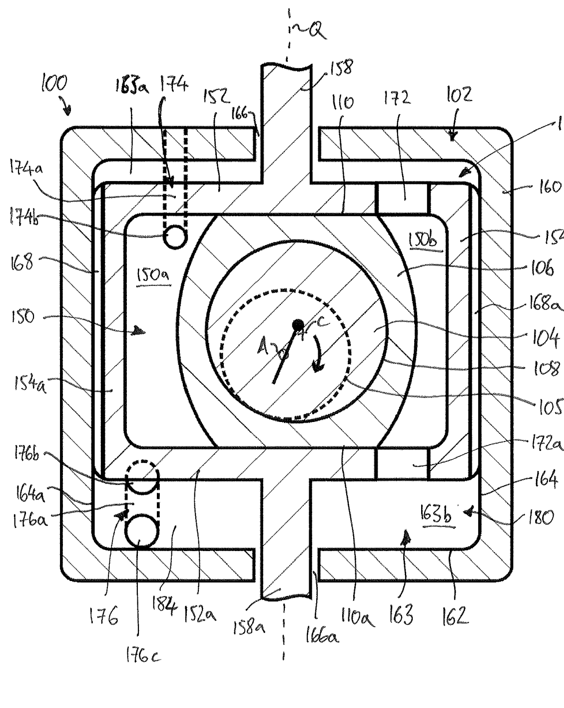

FIGURE 4

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Description

Field of the invention

[0001] This invention relates to a pumping assembly for pumping a fluid. In particular, but not exclusively, the invention relates to a pumping assembly that functions both as a transfer pump and as a high-pressure fuel pump, suitable for use in 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 54, shown schematically in Figure 3, for driving reciprocal movement of the pumping element 52. It should be noted that the cross-sectional views of the pumping head 50 and the drive assembly 54 in Figures 2 and 3 respectively are not to scale.

[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 chamber 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 motion along a pumping axis Q by the drive assembly 54, 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 passage 63, through the inlet valve 62. The fuel supply passage 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 passage 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] Referring to Figure 3, the drive assembly 54 comprises a housing 70, also known as a cam box, which houses a cylindrical cam 72. The housing 70 is only partially shown in Figure 3. The cam 72 is driven in eccentric rotational movement by a drive shaft (not shown in Figure 3) that extends through the housing 70, so that the cylinder axis C of the cam describes a circular path around the axis A of the drive shaft (which extends normal to the drawing plane in Figure 3) as the drive shaft rotates. The path described by the edge of the cam 72 as it rotates is indicated by the dashed line P in Figure 3. The drive shaft has a smaller diameter than the cam 72.

[0012] The cam 72 carries a cam ring or rider 74, which includes a central cylindrical aperture 76 for receiving the cam 72. The rider 74 includes a flattened surface region or flat 78, which is arranged to cooperate with a cam follower or tappet 80 that acts as a drive member for the pumping element 52. The cam 72 is free to rotate in the aperture 76, so that the orientation of the flat 78 of the rider 74 remains horizontal in use.

[0013] The tappet 80 is guided for reciprocal movement through an opening 82 in the housing 70, and is coupled to the pumping element 52 so that movement of the tappet 80 causes movement of the pumping element 52.

[0014] The tappet 80 includes a flat base surface 84 that is held in sliding contact with the flat 78 of the cam rider 74 by a biasing spring 86. The housing 70 contains a lubricant (conveniently fuel) that lubricates the sliding interfaces between the tappet 80 and the rider 74 and between the tappet and the wall of the opening 82.

[0015] As the drive shaft rotates, the cam 72 carries the rider 74 in a path having an upward component, towards the opening 82 in the housing 70. By virtue of the upward component of movement of the rider 74, the tappet 80 is driven upwards by the rider 74, so as to drive the forward stroke of the pumping element (52 in Figure 2). Once the cam 72 reaches its uppermost position (top dead centre or TDC), continued rotation of the drive shaft results in the cam 72 carrying the rider 74 in a path having a downward component, away from the opening 82 in the housing 70. The biasing spring 86 keeps the tappet 80 in engagement with the flat 78 of the rider 74, so that the tappet 80 moves downwards and the pumping element (52 in Figure 2) is therefore driven by the biasing spring 86 in its return stroke. When the cam 72 reaches its lowermost position (bottom dead centre or BDC), the pumping cycle repeats as the drive shaft continues to rotate.

[0016] A second pumping head (not shown) may be mounted diametrically opposite the pumping head 50 shown in Figure 3. In this case, a pumping element (not shown) associated with the second pumping head is driven by a tappet (not shown) that cooperates with a second flat 78a provided on the rider 74. The second pumping head provides the high-pressure pump 26 with extra pumping capacity, and also helps to balance the moving components of the pump 26. As one of the pumping elements undergoes its forward stroke, the other one of the pumping elements undergoes its return stroke, and vice versa.

[0017] The transfer pump 24 must be capable of delivering a sufficient volume of fuel to the high-pressure pump 26 to match the peak fuel output of the high-pressure pump. This requirement means that the transfer pump 24 must be capable of a relatively high flow rate at relatively low pressure, compared to the high-pressure pump.

[0018] Typically, the transfer pump 24 is of the vane or blade type. Conveniently, the transfer pump 24 is driven by the same drive shaft as the cam 72 of the high-pressure pump 26, so that an increase in pumping speed of the high-pressure pump 26 also causes an increase in pumping speed of the transfer pump 24. Furthermore, the transfer pump 24 is often housed in the same unit as the high-pressure pump 26. In other known arrangements, the transfer pump is remote from the high-pressure pump 26 and is driven by a separate drive source, such as an electric motor.

[0019] Against this background, the inventors of the present invention have recognised that it would be desirable to provide a high-pressure fuel pump that does not require a separate transfer pump arrangement.

Summary of the invention

[0020] From a first aspect, the present invention resides in a pumping assembly having a high-pressure pumping stage and an integrated transfer pumping stage for pumping fluid from a fluid source to the high-pressure pumping stage. The pumping assembly comprises a cam arranged for eccentric rotation about a drive shaft axis, a cam rider driveable by the cam, a cam follower that cooperates with the rider and being arranged for reciprocal movement parallel to a cam follower axis that is perpendicular to the drive shaft axis in response to rotation of the cam, a high-pressure pumping head having a high-pressure pumping chamber, and a pumping element driven by the cam follower and arranged to reduce the volume of the high-pressure pumping chamber during a forward stroke and to increase the volume of the high-pressure pumping chamber during a return stroke. The forward and return strokes together define a pumping cycle of the pumping assembly.

[0021] The pumping assembly further comprises a first chamber, inlet means for allowing fluid flow into the first chamber, and outlet means for receiving fluid from the first chamber and for delivering fluid to the high-pressure pumping head. Rotation of the cam about the driveshaft axis causes an increase in volume of the first chamber during a first part of the pumping cycle and a decrease in volume of the first chamber during a second part of the pumping cycle, so as to effect a transfer pumping of fluid from the inlet means to the outlet means for delivery to the high-pressure pumping head.

[0022] The present invention therefore takes advantage of the relative movement of components in a high-pressure pump drive mechanism to perform the function of a low-pressure transfer pump. By integrating the transfer pump function with the high-pressure pump, a more compact arrangement is achieved compared to prior art arrangements having separate transfer and high-pressure pumps. Furthermore, the component count is reduced compared to a two-pump arrangement, so the pumping assembly of the present invention is more reliable, easier to manufacture, and less costly than a conventional pumping assembly. Also, since the transfer pump function can be obtained using only the moving parts required for driving the high-pressure pumping action, the pumping assembly of the invention is efficient.

[0023] Preferably, the first chamber is internal to the cam follower. The cam follower may receive the rider. Accordingly, the present invention can employ volume changes that occur through cooperation of the cam follower and the rider to effect the transfer pumping function.

[0024] The outlet means may comprise an outlet for delivering fluid to the high-pressure pumping head, and a second chamber in communication with the outlet. Rotation of the cam about the driveshaft axis causes a decrease in volume of the second chamber during the first part of the pumping cycle, and an increase in volume of the second chamber during the second part of the pumping cycle.

[0025] The first chamber may be defined in part by the cam follower and in part by a first surface of the rider, and the second chamber may be defined in part by the cam follower and in part by a second, opposite surface of the rider.

[0026] In one embodiment, in the first part of the pumping cycle, fluid is drawn from the inlet means into the first chamber, and fluid is pumped from the second chamber to the outlet. In the second part of the pumping cycle, fluid may be transferred from the first chamber into the second chamber.

[0027] The pumping assembly may further comprise transfer means for allowing fluid flow from the first chamber to the second chamber during the second part of the pumping cycle, and for restricting fluid flow from the first chamber to the second chamber during the first part of the pumping cycle. For example, the transfer means may comprise a transfer port, and the cam follower may be arranged to occlude the transfer port during the first part of the pumping cycle to restrict the flow of fluid through the transfer means.

[0028] The pumping assembly may further comprise a housing within which the cam, the cam rider and the cam follower are received, and the outlet means may further comprise a third chamber defined in part by the housing and in part by the cam follower. In such a case, the cam follower may include fluid flow means that allows fluid flow between the second chamber and the third chamber.

[0029] The inlet means preferably allows fluid flow into the first chamber during at least a portion of the first part of the pumping cycle, and the inlet means preferably restricts fluid flow into the first chamber during at least a portion of the second part of the pumping cycle. For example, the inlet means may comprise an inlet port, and the cam follower may be arranged to occlude the inlet port during at least a portion of the second part of the pumping cycle to restrict the flow of fluid through the inlet means.

[0030] In one embodiment, the cam follower comprises first and second cross members that cooperate with the rider at first and second sliding interfaces, respectively. The forward stroke of the pumping element may be driven when the rider thrusts against the first cross member during movement of the rider, and the return stroke of the pumping element is driven when the rider thrusts against the second cross member during movement of the rider. Advantageously, in this embodiment, it is not necessary to provide a biasing spring or other biasing means to drive the return stroke of the pumping element.

[0031] The cam follower may comprise first and second connecting members that connect respective ends of the first cross member to corresponding ends of the second cross member, such that the first and second cross members and the first and second connecting members define a volume for receiving the rider and the cam.

[0032] In a second aspect, the present invention resides in a combined transfer pump and high-pressure fuel pump for a fuel injection system, comprising a pumping assembly according to the first aspect of the invention.

Brief description of the drawings

[0033]

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.

Figures 2 and 3, which have also been referred to above, are schematic cross-sectional views of a pumping head and a drive assembly, respectively, of a conventional high-pressure fuel pump for use in the fuel injection system of Figure 1.

[0034] Embodiments of 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 4 is a schematic cross-sectional view of a pumping assembly according to a first embodiment of the present invention;

Figures 5(a) to 5(c) are schematic front, side and perspective views of a rear cover plate of the pumping assembly of Figure 4;

Figures 6(a) to 6(c) are schematic cross-sectional views illustrating the operation of the pumping assembly of Figure 4;

Figures 7(a) and 7(b) are schematic flow diagrams illustrating the flow path through the pumping assembly of Figure 4 during operation;

Figure 8 is a schematic cross-sectional view of a pumping assembly according to a second embodiment of the present invention;

Figure 9 is a schematic back view of a front cover plate of the pumping assembly of Figure 8;

Figures 10(a), 10(b) and 10(c) are schematic front, side and perspective views respectively of a cam follower of the pumping assembly of Figure 8; and

Figures 11 (a) and 11 (b) are schematic cross-sectional views illustrating the operation of the pumping assembly of Figure 8.

[0035] Throughout this description, terms such as 'front', 'rear', 'upper', 'lower', 'left', 'right', 'horizontal', 'vertical' 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

[0036] Figure 4 shows a drive assembly 100 for a pumping assembly according to a first embodiment of the invention. The drive assembly 100 includes a housing 102, which houses a cylindrical cam 104. The cam 104 is mounted eccentrically on a drive shaft, the position of which is indicated by the dashed line 105 in Figure 4. The cylinder axis C of the cam 104 is parallel to, but offset from, the axis A of the drive shaft 105.

[0037] The cam 104 carries a cam ring or rider 106 that includes parallel first and second flattened regions or flats 110, 110a, disposed either side of a cam-receiving aperture 108. The cam 104 is rotatable relative to the rider 106 so that, in use, the flats 110, 110a remain horizontal (in the orientation shown in Figure 4).

[0038] A cam follower 112 cooperates with the rider 106, and is guided for linear reciprocal movement along a pumping axis Q. The cam follower 112 defines a generally cuboidal internal volume 150, in which the rider 106 is slidably received.

[0039] The cam follower 112 includes a first or upper horizontal member 152 and a parallel second or lower horizontal member 152a, each of which extend in a plane that lies normal to the pumping axis Q. The cam follower further includes a first vertical member 154 that connects the right-hand ends of the vertical members 152, 152a, and a second vertical member 154a that connects the left-hand ends of the horizontal members 152, 152a. The vertical and horizontal members 152, 152a; 154, 154a define a cage-like structure that encloses the volume 150, and the rider 106, therewithin. The volume 150 is open to the front and rear faces of the cam follower 112, but is closed by front and rear face plates (not shown in Figure 4) of the housing 102.

[0040] The first horizontal member 152 of the cam follower 112 is in sliding contact with the uppermost flat 110 of the rider 106, and the second horizontal member 152a is in sliding contact with the lowermost flat 110a. Therefore two sliding interfaces are defined between the rider 106 and the cam follower 112, each lying in a plane having a normal direction that is parallel to the pumping axis Q.

[0041] First and second drive members 158, 158a project upwardly and downwardly from the first and second horizontal members 152, 152a, respectively, through apertures 166, 166a in the housing 102. Each drive member 158, 158a drives an associated pumping element (not shown). The drive assembly 100 is provided with upper and lower high-pressure pumping heads (not shown), disposed opposite one another across the drive shaft axis A. Each pumping head receives a respective upper and lower one of the pumping elements. The pumping heads may be of a known type, such as that described above with reference to Figure 2, in which a forward stroke of the associated pumping element causes the reduction in volume of a pumping chamber, and a return stroke of the pumping element causes the increase in volume of the pumping chamber.

[0042] The housing 102 comprises a wall part 160, which is visible in cross-section in Figure 4, a front face plate (not shown) and a rear face plate 180 (also shown in Figures 5(a) to (c) and described in more detail below). The face plates are attachable to the front and rear sides of the wall part 160, respectively, and include apertures that allow the drive shaft to pass through the housing 102 (the aperture 182 in the rear face plate 180 is visible in Figures 5(a) and 5(c)).

[0043] As shown most clearly in Figure 4, an inner wall 162 of the wall part 160 of the housing 102 defines a generally cuboidal housing volume 163 in which the cage-like structure of the rider 112 is received. The inner wall 162 includes first and second vertical guide surfaces 164, 164a, and the first and second vertical members 154, 154a respectively of the cam follower 112 are in sliding contact with the vertical guide surfaces 164, 164a. The cam follower 112 can therefore move up and down in guided movement within the housing volume 163.

[0044] The front and rear faces of the cam follower 112 are in sliding contact with the inside surfaces of the front and rear face plates of the housing 102 in use. Accordingly, cooperation between the front and rear faces of the cam follower 112 and the face plates of the housing 102 also acts to guide the movement of the cam follower 112.

[0045] Also, the front and rear faces (not shown) of the rider 106 are in sliding contact with the front and rear face plates of the housing 102. Accordingly, the internal volume 150 of the cam follower 112 is divided into two chambers 150a, 150b by the rider 106.

[0046] A first part of the internal volume 150, known hereafter as a first chamber or transfer pump chamber 150a, is defined by the cam follower 112 on its top, bottom and left-hand sides (referring to the orientation in Figure 4), by the rider 106 on its right-hand side and by the front and rear face plates on its front and back faces, respectively.

[0047] A second part of the internal volume 150, known hereafter as a second chamber or outlet chamber 150b, is defined by the cam follower 112 on its top, bottom and right-hand sides (referring to the orientation in Figure 4), by the rider 106 on its left-hand side and by the front and rear face plates on its front and back sides, respectively.

[0048] Similarly, the internal housing volume 163 is divided into two parts 163a, 163b by the cam follower 112. An upper housing volume 163a is defined by the housing wall 162 on its top, left and right sides, by the cam follower 112 on its bottom side, and by the front and rear face plates on its front and back sides, respectively. A lower housing volume 163b is defined by the housing wall 162 on its bottom, left and right sides, by the cam follower 112 on its top side, and by the front and rear face plates on its front and back sides, respectively.

[0049] The cam follower 112 is provided with fluid flow means in the form of first and second vertically-extending channels 168, 168a in the outer surfaces of the first and second vertical members 154, 154a of the cam follower 112, respectively. The channels 168, 168a provide a vertical fluid flow path to allow fluid to flow past the cam follower 112 between the upper and lower housing volumes 163a, 163b as the cam follower 112 reciprocates up and down within the housing.

[0050] Further fluid flow means are provided in the form of first and second apertures or drillings 172, 172a that extend through the first and second vertical members 154, 154a of the cam follower 112, respectively. The drillings 172, 172a allow fluid to flow freely between the outlet chamber 150b and the upper and lower housing volumes 163a, 163b.

[0051] By virtue of the fluid flow means 168, 168a, 172, 172a, the outlet chamber 150b and the upper and lower housing volumes 163a, 163b together form a single connected space for fluid, the volume of which depends on the position of the rider 106.

[0052] The fluid flow means 168, 168a, 172, 172a do not permit free fluid flow between the transfer pump chamber 150a and the upper or lower housing volumes 163a, 163b, or between the transfer pump chamber 150a and the outlet chamber 150b of the internal cam follower volume 150.

[0053] Instead, the transfer pump chamber 150a is arranged to communicate selectively with inlet means in the form of an inlet passage 174, which is connected to a fluid source (not shown), and to communicate selectively with the lower housing volume 163b, and hence the outlet chamber 150b, by way of transfer means in the form of a transfer passage 176.

[0054] Referring additionally to Figures 5(a) to 5(c), the inlet passage 174 and the transfer passage 176 are provided in the rear face plate 180 of the housing 102. The inlet passage 174 comprises a vertical blind drilling 174a in the plane of the rear face plate 180, and a horizontal blind drilling 174b that intersects with the vertical drilling 174a and opens onto the front face 184 of the rear face plate 180 (i.e. the innermost face of the rear face plate 180 when the housing 102 is assembled). The vertical drilling 174a opens onto the top face 186 of the rear face plate 180, as shown most clearly in Figure 5(c). In use, a fluid supply (not shown), for example from a tank, is connected to the inlet passage 174 by way of the vertical drilling 174a.

[0055] The transfer passage 176 comprises a vertical blind drilling 176a that extends in the plane of the rear face plate 180, and two vertically-spaced, horizontal blind drillings 176b, 176c, each of which intersect the vertical drilling 176a and open onto the front face 184. For manufacturing reasons, the vertical drilling 176a may extend to the bottom face 188 of the rear face plate 180. However, the vertical drilling 176a is blocked at its lowermost end, so that no fluid flow can reach the bottom face 188 of the face plate 180. The transfer passage 176 therefore defines a 'C'-shaped flow path for fluid through the upper horizontal drilling 176b, the vertical drilling 176a and the lower horizontal drilling 176c.

[0056] In general terms, operation of the drive assembly 100 to drive the pumping elements in the high-pressure pumping heads is similar to the operation of the conventional drive assembly shown in Figure 3. As the cam 104 rotates, the vertical component of movement of the rider 106 is converted to movement of the cam follower 112 in a direction parallel to the pumping axis Q, so as to drive the forward and return strokes of the pumping elements. Unlike in the conventional drive assembly, in the assembly shown in Figure 4 both the forward and return strokes of each pumping element are driven by the cooperative movement of the rider 106 against the cam follower 112. Therefore, the drive assembly 100 of the invention advantageously does not require biasing springs or other biasing means for driving the return strokes of the pumping elements.

[0057] It will be understood from Figure 4 that, due to the configuration of the cam 104, the rider 106 and the cam follower 112, rotation of the cam 104 causes a cyclical variation in the volumes of both the transfer pump chamber 150a and the outlet chamber 150b. The volume change of the outlet chamber 150b during a pumping cycle is opposite in phase to the volume change of the transfer pump chamber 150a. Said another way, during a first part of the pumping cycle, rotation of the cam 104 about the driveshaft axis A causes an increase in volume of the transfer pump chamber 150a and a corresponding decrease in volume of the outlet chamber 150b, and during a second part of the pumping cycle, rotation of the cam 104 about the driveshaft axis A causes a decrease in volume of the transfer chamber 150a and an increase in volume of the outlet chamber 150b. It will be understood that, at some stages during the pumping cycle, there may be no significant change in the volume of the chambers 150a, 150b. Accordingly, the first and second parts of the pumping cycle need not necessarily comprise the entire pumping cycle.

[0058] Operation of the drive assembly 100 will now be described in more detail with reference to Figures 6 (a), 6(b) and 6(c), which show stages in operation of the drive assembly 100 as the drive shaft rotates in a clockwise direction, and also with reference to Figures 7(a) and 7(b), which are schematic diagrams that illustrate fluid flow through the drive assembly 100 during the first and second parts of the pumping cycle, respectively.

[0059] Figure 6(a) shows the drive assembly 100 in a configuration where the cam 104 has just passed TDC, and the cam follower 112 is moving downwards from its point of furthest upward travel. Therefore the pumping element driven by the upper drive member 158 is beginning its return stroke, and the pumping element driven by the lower drive member 158a is beginning its forward stroke. The cam rider 106 is driven downwards and to the right by the movement of the cam 102.

[0060] In this configuration, the cam follower 112 is positioned so that the horizontal drilling 174b of the inlet passage 174 opens into the transfer pump chamber 150a. The upper horizontal drilling 176b of the transfer passage 176 does not open into the transfer pump chamber 150a, but is instead blocked by the lower horizontal member 152a of the cam follower 112. Accordingly, because flow through the transfer passage 176 is blocked, no fluid can flow from the transfer pump chamber 150a into the space comprising the upper and lower housing volumes 163a, 163b, the drillings 172, 172a, and the outlet chamber 150b.

[0061] As the cam 102 continues to rotate, the rider 106 moves to the right with respect to the cam follower 112 (i.e. during the first part of the pumping cycle). The volume of the transfer pump chamber 150a therefore increases, and fluid is drawn in to the transfer pump chamber 150a through the inlet passage 174.

[0062] At the same time, the volume of the outlet chamber 150b decreases. This causes expulsion of fluid from the outlet chamber 150b. The outlet chamber 150b is in communication with the apertures 166, 166a through which the upper and lower drive members 158, 158a emerge, by way of the drillings 172, 172a in the upper and lower cam follower members 152, 152a, and by way of the upper and lower housing volumes 163a, 163b. Accordingly, when the volume of the outlet chamber 150b decreases, fluid is expelled from the housing 102 through the apertures 166, 166a, which serve as an outlet for fluid from the drive assembly 100.

[0063] In use, the fluid expelled through the apertures 166, 166a is received by inlet means of the respective high-pressure pumping heads (not shown). To avoid overpressurisation of the housing 102, a back-leak passage (not shown) may be provided, which provides communication between the outlet chamber 150b and a low-pressure drain (such as the supply tank), by way of a pressure-regulating valve that permits fluid flow to drain if the pressure in the outlet means exceeds a predetermined level.

[0064] The configuration of the drive assembly 100 in Figure 6(a) is illustrated in a simplified form in Figure 7 (a), which shows the fluid flow paths in the drive assembly 100 and in which the reference numbers correspond to the equivalent components in Figures 4 and 6(a). In Figure 7(a), the interaction between the upper horizontal member 152 of the cam follower 112 and the horizontal inlet drilling 174b is represented as an open valve V1, allowing fluid flow from the inlet passage 174 to the transfer pump chamber 150a, and the interaction between the lower horizontal member 152a of the cam follower 112 and the upper transfer passage drilling 176b is represented as a closed valve V2, preventing fluid flow between the transfer pump chamber 150a and the outlet chamber 150b through the transfer passage 176, the housing volume 163 and the drillings 172, 172a.

[0065] It will be appreciated from Figure 7(a) that, in the first part of the pumping cycle, when the rider 106 moves in the direction of the arrow to increase the volume of the transfer pump chamber 150a and to decrease the volume of the outlet chamber 150b, fluid is drawn into the drive assembly 100 through the inlet passage 174 and is simultaneously expelled from the drive assembly 100 through the outlet means (apertures 166, 166a).

[0066] Referring back to Figure 6(a), the horizontal inlet drilling 174b remains open for a time as the cam 102 rotates clockwise from the position shown in Figure 6(a) and the cam follower 112 moves downwards. Eventually, the upper horizontal member 152 of the cam follower 112 occludes the horizontal inlet drilling 174b, stopping flow into the transfer pump chamber 150a, and the lower horizontal member 152a moves beneath the opening of the upper transfer passage drilling 176b, which opens communication between the transfer pump chamber 150a and the outlet chamber 150b, through the transfer passage 176 the upper and lower housing volumes 163a, 163b and the drillings 172, 172a. This configuration is shown in Figure 6(b).

[0067] Once the cam 102 moves beyond 90° to BDC, the rider 106 begins to move towards the left in Figure 6 (b) (i.e. during the second part of the pumping cycle), to decrease the volume of the transfer pump chamber 150a and to increase the volume of the outlet chamber 150b. Figure 6(c) illustrates the configuration when the rider 106 has moved almost to the limit of its leftward motion.

[0068] Figure 7(b) illustrates in a simplified form the configuration of the pumping assembly 100 shown in Figures 6(b) and 6(c), during the second part of the pumping cycle. As a result of the leftward movement of the rider 106 (in the direction of the arrow in Figure 7(b)), the volume of the transfer pump chamber 150a decreases and the volume of the outlet chamber 150b increases. Since fluid can flow between the transfer pump chamber 150a and the outlet chamber 150b through the open transfer passage 176, via the housing volume 163 and the drillings 172, 172a, fluid is transferred from the transfer pump chamber into the outlet chamber 150b.

[0069] On further rotation of the cam 104 in a clockwise direction from the position shown in Figure 6(c), the cam follower 112 moves upwards to open communication between the inlet passage 174 and the transfer pump chamber 150a, and to close communication through the transfer passage 176. The pumping cycle then repeats.

[0070] In this way, the drive assembly 100 performs the function of a low-pressure transfer pump, and is capable of transferring fluid from the inlet passage 174 to the apertures 166, 166a for delivery to inlet means of the pumping heads. The fluid pumped in this way serves to lubricate and cool the sliding interfaces in the drive assembly 100. Also, since the rate of pumping through the drive assembly 100 depends on the speed of rotation of the drive shaft, the rate of pumping automatically increases and decreases to match the speed-dependent output of the high-pressure pumping heads.

[0071] When used in a fuel injection system, a pump assembly including a drive assembly as shown in Figure 4 can be used to replace the transfer pump and the high-pressure fuel pump drive assembly of a conventional fuel injection system. The supply of fuel to the inlet passage 174 of the drive assembly 100 can be regulated by an inlet metering valve, to control the fuel output of the pump assembly.

[0072] A pumping assembly 200 according to a second embodiment of the present invention will now be described with reference to Figure 8, which is a schematic cross-sectional view through the pumping assembly 200, and Figure 9, which shows the back (inside) face 294 of a front cover plate 290 of a housing 202 of the pumping assembly 200. The pumping assembly 200 of the second embodiment of the invention is similar in structure and operation to the pumping assembly 100 of the first embodiment of the invention, and so only the differences will be described in detail.

[0073] The drive assembly 200 of Figure 8 includes a housing 202, which houses a cylindrical cam 204. The cam 204 is mounted eccentrically on a drive shaft, the position of which is indicated by the dashed line 205 in Figure 8. As in the first embodiment of the invention, the cylinder axis C of the cam 204 is parallel to, but offset from, the axis A of the drive shaft. In use, when the drive shaft rotates, the cam 204 rotates eccentrically.

[0074] The cam 204 carries a cam ring or rider 206, which includes parallel first and second flattened regions or flats 210, 210a, disposed either side of the cam 204. The cam 204 is rotatable relative to the rider 206.

[0075] A cam follower 212 cooperates with the rider 206, and is guided for linear reciprocal movement along a pumping axis Q. The cam follower 212 defines an internal volume 250, in which the rider 206 is slidably received. The rider 206 divides the internal volume 250 into a first chamber, known hereafter as a transfer pump chamber 250a, and a second chamber, known hereafter as an outlet chamber 250b, which have the same functions as the equivalent chambers 150a, 150b in the first embodiment of the invention.

[0076] Referring additionally to Figures 10(a), 10b) and 10(c), which show the cam follower 212 of the drive assembly 200 of Figure 8 in isolation, the cam follower 212 includes a first or upper inclined member 252 and a parallel second or lower inclined member 252a, each of which extend at a non-perpendicular angle to the pumping axis Q. The cam follower further includes a first vertical member 254 that extends downwardly from the right-hand end of the first inclined member 252, and a second vertical member 254a that extends upwardly from the left-hand end of the second inclined member 252a. A first curved link member 256 joins the left-hand end of the first inclined member 252 to the top end of the second vertical member 254a, and a second curved link member 256a joins the right-hand end of the second inclined member 252a to the bottom end of the first vertical member 254.

[0077] In this way, the inclined members 252, 252a, the vertical members 254, 254a and the link members 256, 256a define a cage-like structure that encloses the volume 250, and the rider 206, therewithin. The volume 250 is open to the front and rear of the cam follower 212. The front and rear faces of the cam follower 212 are in sliding contact with the back face 294 of the front face plate 290 (shown in Figure 9) and with the front face of a rear face plate 280 (visible in Figure 8) of the housing 200, to close the volume 250.

[0078] As illustrated in Figure 8, the angle of inclination of the flats 210, 210a of the rider 206 matches the angle of inclination of the inclined members 252, 252a of the cam follower 212, so the first inclined member 252 of the cam follower 212 is in sliding contact with the uppermost flat 210 of the rider 206, and so the second inclined member 252a is in sliding contact with the lowermost flat 210a. Therefore two sliding interfaces are defined between the rider 206 and the cam follower 212, each lying in a plane having a normal direction that is inclined at an angle to the pumping axis Q. In this second embodiment, the rider 206 and the cam follower 212 slide with respect to one another along a sliding axis that is inclined at a non-perpendicular angle to the pumping axis Q. Accordingly, in use, both the horizontal and vertical components of movement of the rider 206 are converted to linear movement of the cam follower 212, and an increased stroke length is possible compared to an arrangement such as that shown in Figure 4 in which the sliding axis is perpendicular to the pumping axis Q.

[0079] Referring again to Figure 8 and Figures 10(a) to (c), first and second drive members 258, 258a project upwardly and downwardly from the first and second inclined members 252, 252a, respectively. As in the first embodiment, each drive member 258, 258a cooperates with an associated pumping element (not shown) which is received in a respective pumping head (not shown), for example of the type illustrated in Figure 2. The housing 202 includes first and second apertures 266, 266a, through which the drive members 258, 258a extend.

[0080] The housing 202 defines a housing volume 263 in which the cage-like structure of the cam follower 212 is received. The housing volume 263 has an irregular generally hexagonal cross-section, and is divided into an upper part 263a and a lower part 263b by the cam follower 212.

[0081] The cam follower 212 is provided with fluid flow means to allow the free flow of fluid between the upper and lower housing volumes 263a, 263b, in the form of vertically-extending recesses or channels 268, 268a in the outer surfaces of the first and second vertical members 254, 254a of the cam follower 212. Further fluid flow means in the form of a slot 270 that extends through the first vertical member 254, and a drilling 272a that extends through the second link member 256a of the cam follower 212 allow the free flow of fluid between the outlet chamber 250b and the housing volume 263.

[0082] The fluid flow means 268, 268a, 270, 272a do not permit free fluid flow between the transfer pump chamber 250a and the upper or lower housing volumes 263a, 263b, or between the transfer pump chamber 250a and the outlet chamber 250b.

[0083] Instead, as in the first embodiment of the invention, the transfer pump chamber 250a is arranged to communicate selectively with an inlet passage 274, which is connected to a fluid source (not shown), and to communicate selectively with the upper housing volume 263a by way of a transfer passage 276.

[0084] As shown most clearly in Figure 9, the inlet passage 274 and the transfer passage 276 are provided in the front face plate 290 of the housing 202. The back face 294 of the front face plate 290 (i.e. the internal face, in use) is visible in Figure 9, and the passages 274, 276 in the front face plate 290 are shown as dashed lines in Figure 8 to reveal the positions of the passages 274, 276 with respect to the other components of the assembly 200 when the front face plate 290 is in position on the front of the housing 202.

[0085] The inlet passage 274 comprises a blind drilling 274a in the plane of the front face plate 290, and a perpendicular blind slot 274b that intersects with the drilling 274a and opens onto the back face 294 of the front face plate 290. The drilling 274a opens onto a first peripheral face 296 of the front face plate 290. In use, a fluid supply (not shown), for example from a fuel tank, is connected to the inlet passage 274 by way of an enlarged port region 274c of the inlet passage drilling 274a.

[0086] The transfer passage 276 comprises a blind drilling 276a that extends in the plane of the front face plate 290, and two spaced-apart blind drillings 276b, 276c, each of which intersects the vertical drilling 276a and opens onto the front face 294. For manufacturing reasons, the vertical drilling 276a may extend to a second peripheral face 298 of the front face plate 290. However, the transfer passage drilling 276a is blocked at its lowermost end, so that no fluid flow can reach the second peripheral face 298 of the face plate 290. The transfer passage 276 therefore defines a 'C'-shaped flow path for fluid through the upper drilling 276b, the in-plane drilling 276a and the lower drilling 276c.

[0087] The front face place also includes a drain passage 297, comprising a blind drilling 297a that extends in the plane of the front face plate 290, and a blind drilling 297b that intersects the blind drilling 297a and opens onto the front face 294 of the front face plate 290. The drain passage drilling 297a opens onto a third peripheral face 299 of the front face plate 290, and is connected, in use, to a fluid return or drain line (not shown).

[0088] Operation of the pumping assembly 200 according to the second embodiment of the invention, which is similar to the operation of the pumping assembly 100 of the first embodiment, will now be described with reference to Figures 11 (a) and 11 (b).

[0089] Figure 11(a) shows the pumping assembly 200 during the first part of the pumping cycle, where the rider 206 is moving to the right with respect to the cam follower 212. The inlet passage 274 is positioned such that, in this position of the cam follower 212, the slot 274b is not occluded by the cam follower 212 so that the inlet passage 274 is in communication with the transfer pump chamber 250a. The transfer passage 276 is positioned such that both the upper and lower drillings 276b, 276c of the transfer passage 276 open into the transfer pump volume 250a, so no fluid can flow between the transfer pump chamber 250a and the internal volume 263a through the transfer passage 276.

[0090] As the rider 206 moves to the right in Figure 11 (a), the volume of the transfer pump chamber 250a increases, and fluid is drawn into the transfer pump chamber 250a through the inlet passage 274. At the same time, the volume of the outlet chamber 250b decreases, and so fluid is expelled from the outlet chamber 250b, through the slot 270, and drilling 272a of the fluid flow means, into the upper and lower housing volumes 263a, 263b and out through the apertures 266, 266a, which serve as outlet means. As in the first embodiment, the fluid expelled through the apertures 266, 266a is conveyed to the high-pressure pumping heads (not shown). Excess pressure can be relieved via the drain passage 297, which remains open throughout operation and which communicates to a low-pressure drain via a pressure-limiting valve.

[0091] As the cam continues to rotates, the cam follower 212 moves towards the position shown in Figure 11 (b). At this point, the inlet slot 274b is occluded by the cam follower 212, so that the inlet passage 274 is closed. The upper drilling 276b of the transfer passage 276 now opens into the upper housing volume 263a, and the lower drilling 276c of the transfer passage 276 opens into the transfer pump chamber 250a.

[0092] As the rider 206 moves to the left in Figure 11 (b), in the second part of the pumping cycle, the volume of the transfer pump chamber 250a is reduced and the volume of the outlet chamber 250b increases, so that fluid is transferred into the outlet chamber 250b ready for another pumping cycle. In this way, as in the first embodiment of the invention, the drive assembly 200 performs the function of a low-pressure transfer pump, and is capable of transferring fluid from the inlet passage 274 to the apertures 266, 266a for delivery to inlet means of the pumping heads.

[0093] It will be appreciated that the embodiments described above are examples only of the present invention, and that many variations and modifications are possible.

[0094] For example, in the embodiments described above, a drive member of the cam follower cooperates with a pumping element. The drive member and pumping element may be integrally formed, for example so that a distal end of the drive member forms the pumping element. The pumping element may instead be a separate component that is attached to or otherwise connected to the drive member. Similarly, the drive member may be a separate component that is attached to the cam follower. The pumping element, the drive member and the cam follower may be integrally formed as one component.

[0095] Similarly, the members that make up the cage-like cam follower may be parts of a single, integrally formed component, or may be separate or combined components that are assembled to form the cam follower.

[0096] The fluid flow means that allow fluid flow past the cam follower as it reciprocates within the housing volume may be embodied in a different form to the channels described above. For example, channels or flow passages could be provided in the housing wall, in addition to or instead of the channels in the cam follower faces.

[0097] The cam follower may take any suitable form. For example, the cam follower may be of any suitable design that provides two parallel faces for sliding engagement with the flats of the rider, and means for guiding the cam follower in linear reciprocal movement.

[0098] Similarly, the inlet passage and transfer passage may be provided in any suitable position, orientation and form. For example, the inlet passage and/or the transfer passage may be provided in the front face plate of the housing.

[0099] In the embodiments described above, the control of fluid flow through the inlet passage and/or the transfer passage is by way of the above-described interactions between the respective passages and the cam follower. In this case the arrangement of the inlet passage and/or the transfer passage must be such as to permit such interactions. Such an arrangement gives rise to a simple design with a low part count.

[0100] In other embodiments, however, different ways of controlling fluid flow through the inlet passage and/or the transfer passage could be provided. In one example, the inlet passage is arranged to open permanently into the transfer pump chamber, and flow through the inlet passage is controlled by a suitable valve, such as a non-return valve that opens when the volume of the transfer pump chamber increases. Similarly, the transfer passage could provide a permanent connection between the transfer pump chamber and the outlet chamber, with fluid flow through the transfer pump chamber being controlled by a suitable valve. Again, a non-return valve, which allows flow through the transfer passage when the volume of the transfer pump chamber increases and the volume of the outlet chamber decreases, would be suitable.

[0101] Conceivably, the transfer pumping function of the pumping assembly could be effected using a different configuration to that described in the embodiments above. For example, a transfer pump chamber could be defined in part by the cam follower and in part by the housing (for example a volume equivalent to the volume labelled 163a in Figure 4, which undergoes a cyclical volume change as the cam rotates). In this configuration, the transfer pump chamber could be connected to an inlet that supplies fluid to the transfer pump chamber when the volume of the transfer pump chamber increases, and to an outlet from the housing that delivers fluid to the high-pressure pumping head when the volume of the transfer pump chamber decreases. In such a case, the outlet chamber could be omitted.

[0102] When the pumping assembly is used to supply fuel at high pressure to a rail in a fuel injection system, the inlet passage is preferably connected to a source of fuel, such as a fuel tank, through an inlet metering valve. By controlling the fuel flow through the inlet metering valve, the volume of fuel is pumped at low pressure to the pumping heads, and consequently the volume of fuel that is pumped at high pressure to the rail, can be controlled to regulate the pressure of the fuel rail. In an alternative arrangement, the inlet means is connected directly to the source of fuel, and the inlet metering valve controls the flow of fuel from the outlet means to the high-pressure pumping heads.

[0103] In the embodiments described above, the outlet means is embodied as apertures in the housing through which the drive members for the high-pressure pumping elements extend. However, it will be appreciated that alternative outlet means could be provided, such as one or more outlet ports or passages that extend through the housing. In such cases, the drive members may be a sliding fit in the apertures.

[0104] It will also be appreciated that the pumping assembly could be arranged to drive only one high-pressure pumping head, instead of the two pumping heads described. It is also conceivable that more than two pumping heads could be provided, with a cam follower having a corresponding number of drive members to cooperate with a corresponding number of pumping elements.

[0105] Although the pumping assembly of the present invention is particularly suitable for use as a high-pressure fuel pump of a fuel injection system, it will be appreciated that the pumping assembly could also be used for any other pumping application with similar requirements.

[0106] It will be appreciated that the embodiments described above are examples only of the present invention, and that many other modifications and variations of the invention not explicitly disclosed above 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 assembly having a high-pressure pumping stage and an integrated transfer pumping stage for pumping fluid from a fluid source to the high-pressure pumping stage, the pumping assembly comprising:

a cam (104; 204) arranged for eccentric rotation about a drive shaft axis (A);
a cam rider (106; 206) driveable by the cam (104; 206);
a cam follower (112; 212) cooperable with the rider (106; 206), the cam follower (112; 212) being arranged for reciprocal movement parallel to a cam follower axis (Q) that is perpendicular to the drive shaft axis (A) in response to rotation of the cam (104; 204);
a high-pressure pumping head having a high-pressure pumping chamber; and
a pumping element driven by the cam follower (112; 212) and arranged to reduce the volume of the high-pressure pumping chamber during a forward stroke and to increase the volume of the high-pressure pumping chamber during a return stroke, the forward and return strokes together defining a pumping cycle of the pumping assembly;
the pumping assembly further comprising:

a first chamber (150a; 250a);
inlet means (174; 274) for allowing fluid flow into the first chamber (150a; 250a); and
outlet means (150b, 163, 166, 166a; 250b, 263, 266, 266a) for receiving fluid from the first chamber (150a; 250a) and for delivering fluid to the high-pressure pumping head;
wherein rotation of the cam (104; 204) about the driveshaft axis (A) causes an increase in volume of the first chamber (150a; 250a) during a first part of the pumping cycle and a decrease in volume of the first chamber (150a; 250a) during a second part of the pumping cycle, so as to effect a transfer pumping of fluid from the inlet means (174; 274) to the outlet means (150b, 163, 166, 166a; 250b, 263, 266, 266a) for delivery to the high-pressure pumping head.

2. A pumping assembly according to Claim 1, wherein the first chamber (150a; 250a) is internal to the cam follower (112; 212).

3. A pumping assembly according to Claim 1 or Claim 2, wherein the outlet means comprises an outlet (166, 166a; 266, 266a) for delivering fluid to the high-pressure pumping head, and a second chamber (150b; 250b) in communication with the outlet (166, 166a; 266, 266a); wherein rotation of the cam (104; 204) about the driveshaft axis (A) causes a decrease in volume of the second chamber (150b; 250b) during the first part of the pumping cycle, and an increase in volume of the second chamber (150b; 250b) during the second part of the pumping cycle.

4. A pumping assembly according to Claim 3, wherein the first chamber (150a; 250a) is defined in part by the cam follower (112; 212) and in part by a first surface of the rider (106; 206), and wherein the second chamber (150b, 250b) is defined in part by the cam follower (112; 212) and in part by a second, opposite surface of the rider (106; 206).

5. A pumping assembly according to Claim 3 or Claim 4, wherein, in the first part of the pumping cycle, fluid is drawn from the inlet means (174; 274) into the first chamber (150a; 250a), and fluid is pumped from the second chamber (150b; 250b) to the outlet (166, 166a; 266, 266a).

6. A pumping assembly according to Claim 5, wherein, in the second part of the pumping cycle, fluid is transferred from the first chamber (150a; 250a) into the second chamber (150b; 250b).

7. A pumping assembly according to Claim 6, further comprising transfer means (176; 276) for allowing fluid flow from the first chamber (150a; 250a) to the second chamber (150b; 250b) during the second part of the pumping cycle, and for restricting fluid flow from the first chamber (150a; 250a) to the second chamber (150b; 250b) during the first part of the pumping cycle.

8. A pumping assembly according to Claim 7, wherein the transfer means (176) comprises a transfer port (176b), and wherein the cam follower (112) is arranged to occlude the transfer port (176b) during the first part of the pumping cycle to restrict the flow of fluid through the transfer means (176).

9. A pumping assembly according to any of Claims 3 to 8, further comprising a housing (102; 202) within which the cam (104; 204), the cam rider (106; 206) and the cam follower (112; 212) are received, and wherein the outlet means further comprises a third chamber (163; 263) defined in part by the housing (102; 202) and in part by the cam follower (112; 212).

10. A pumping assembly according to Claim 9, wherein the cam follower (112; 212) includes fluid flow means (172; 172a) that allows fluid flow between the second chamber (150b; 250b) and the third chamber (163; 263).

11. A pumping assembly according to any preceding claim, wherein the inlet means (174; 274) allows fluid flow into the first chamber (150a; 250a) during at least a portion of the first part of the pumping cycle; and wherein the inlet means (174; 274) restricts fluid flow into the first chamber (150a; 250a) during at least a portion of the second part of the pumping cycle.

12. A pumping assembly according to Claim 11, wherein the inlet means (174; 274) comprises an inlet port (174b; 274b); and wherein the cam follower (112; 212) is arranged to occlude the inlet port (174b; 274b) during at least a portion of the second part of the pumping cycle to restrict the flow of fluid through the inlet means (174; 274).

13. A pumping assembly according to any preceding claim, wherein the cam follower (112; 212) comprises first and second cross members (152, 152a; 252, 252a) that cooperate with the rider (106; 206) at first and second sliding interfaces, respectively;
and wherein the forward stroke of the pumping element is driven when the rider (106; 206) thrusts against the first cross member (152; 252) and the return stroke of the pumping element is driven when the rider (106; 206) thrusts against the second cross member (152a; 252a) during movement of the rider (206; 306).

14. A pumping assembly according to Claim 13, wherein the cam follower (112; 112) comprises first and second connecting members (154, 154a; 254, 254a, 256, 256a) that connect respective ends of the first cross member (152; 252) to corresponding ends of the second cross member (152a; 252a), such that the first and second cross members (152, 152a; 252, 252a) and the first and second connecting members (154, 154a; 254, 254a, 256, 256a) define a volume (150; 250) for receiving the rider (106; 206) and the cam (104; 204).

15. A fuel pump for a fuel injection system, comprising a pumping assembly (100; 200) according to any preceding Claim.

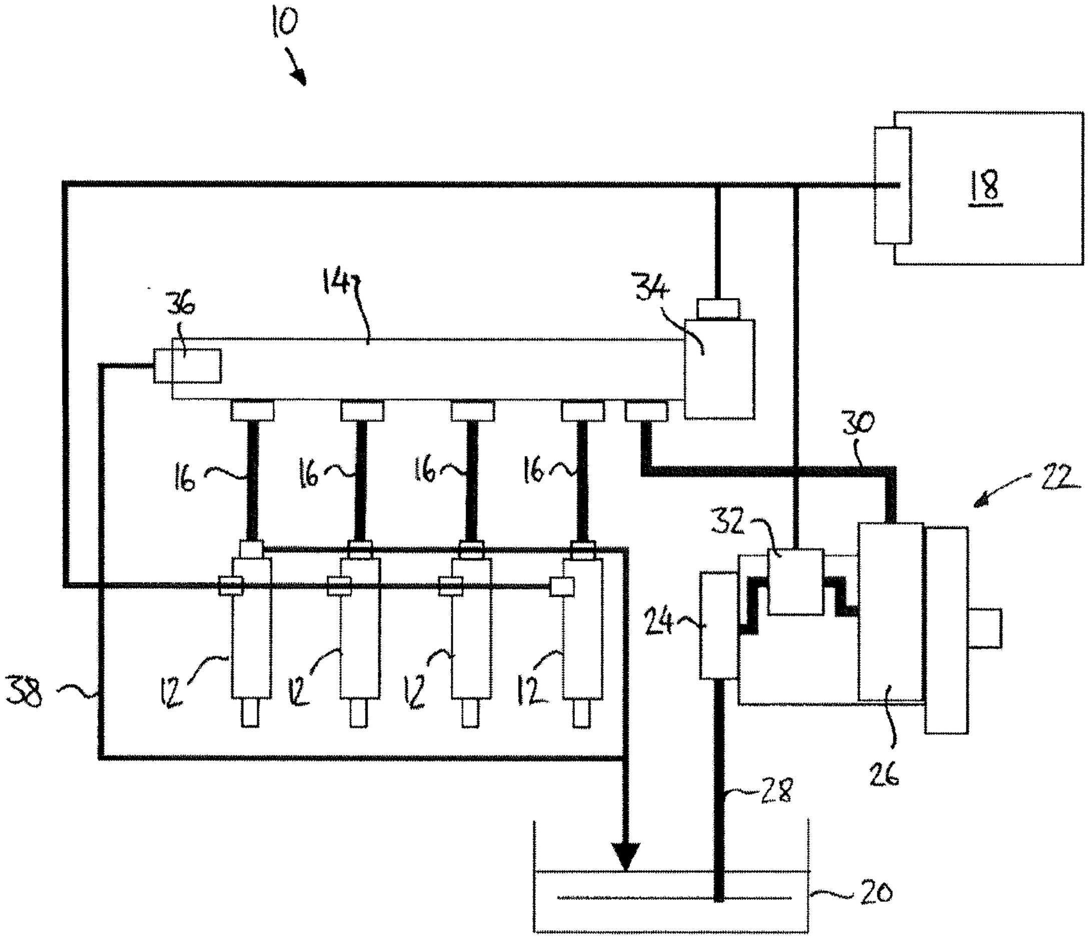

FIGURE 1

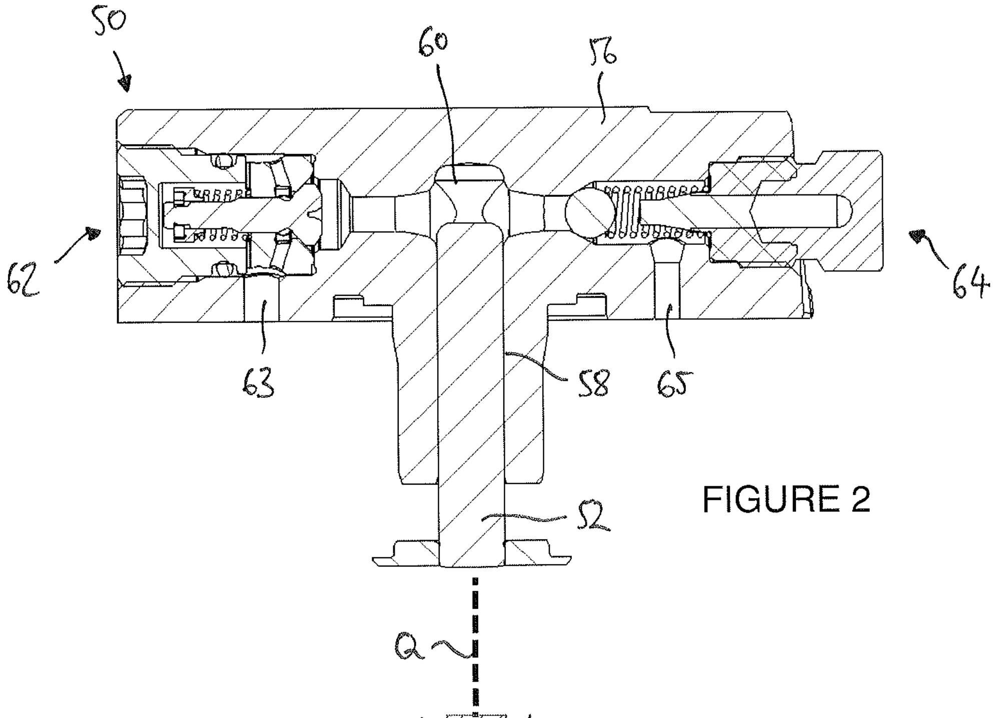

FIGURE 2

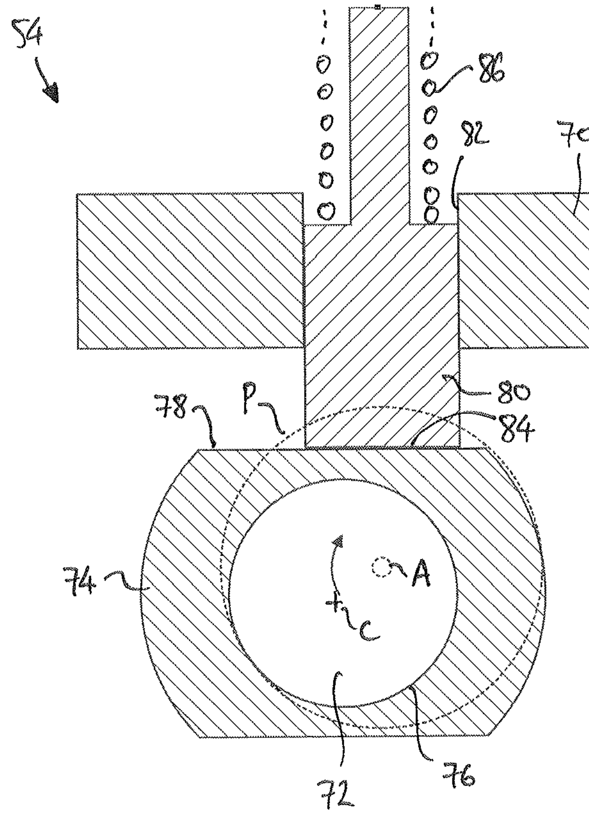

FIGURE 3

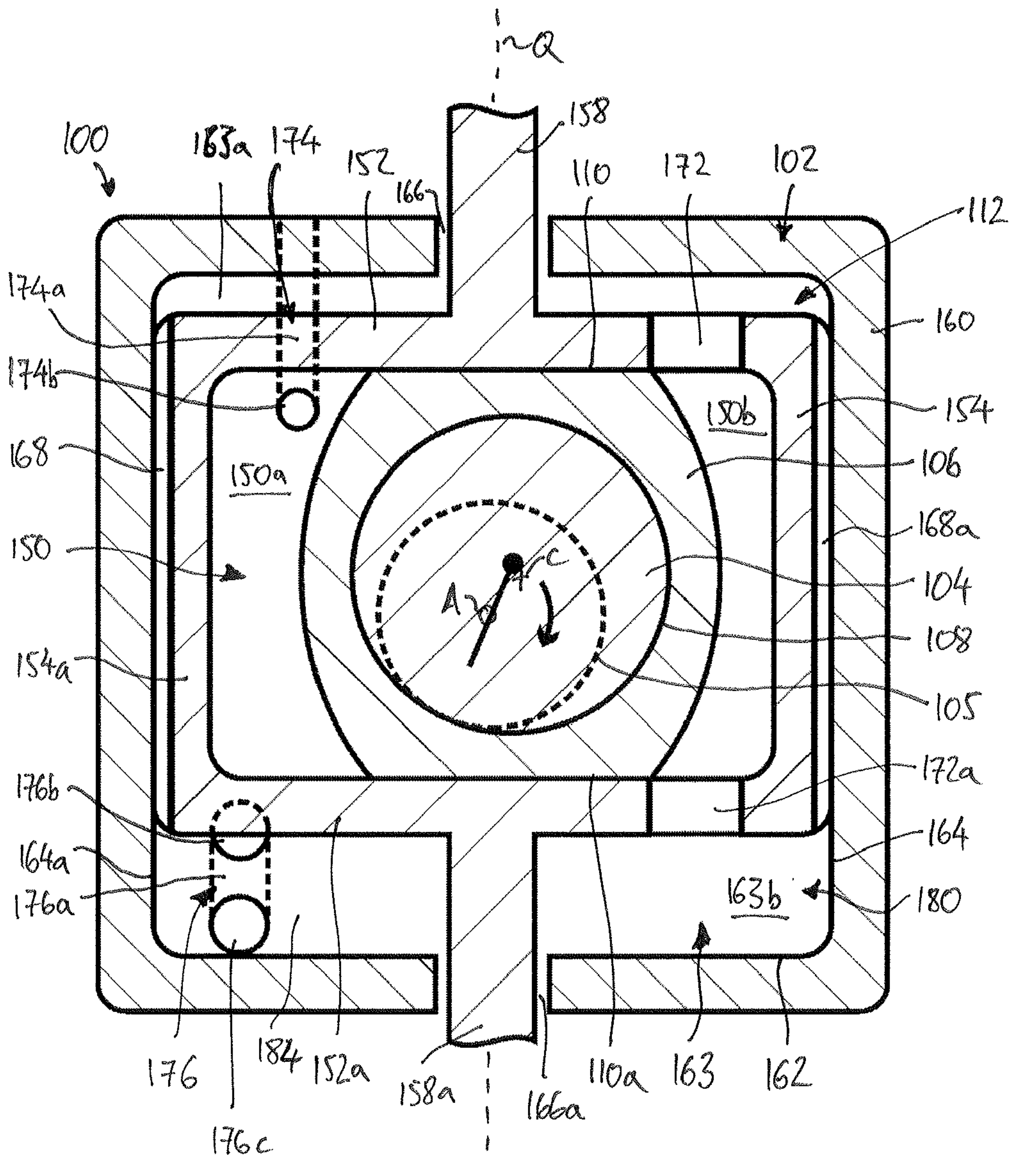
Q
100
163a
174
152
166
158
110
172
102
112
174a
160
174b
154
150b
168
150a
106
168a
150
104
A
C
108
154a
105
172a
176b
164
164a
163b
180
176a
176
184
152a
158a
166a
110a
163
162
176c

FIGURE 4

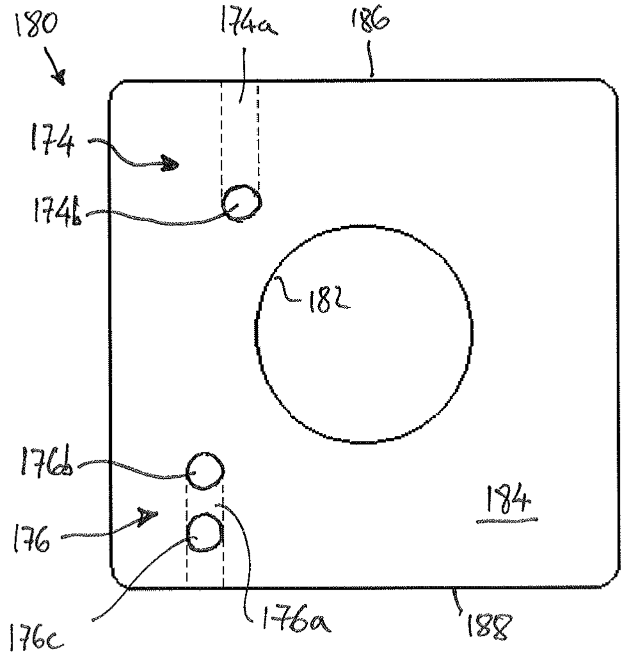

FIGURE 5(a)

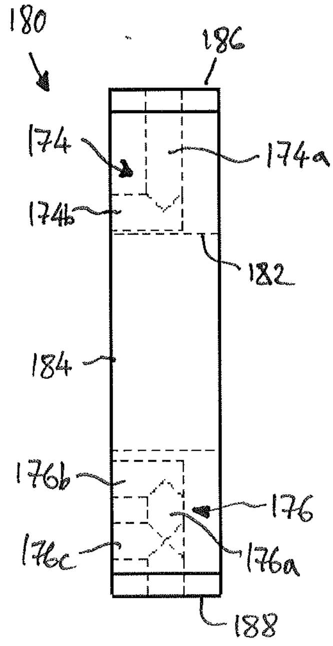

FIGURE 5(b)

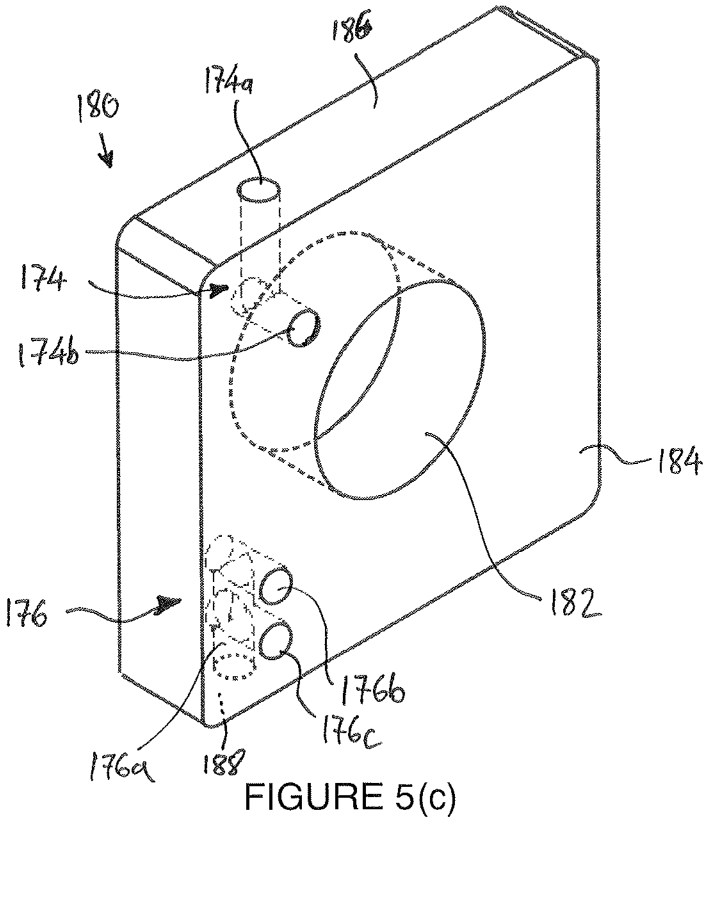

FIGURE 5(c)

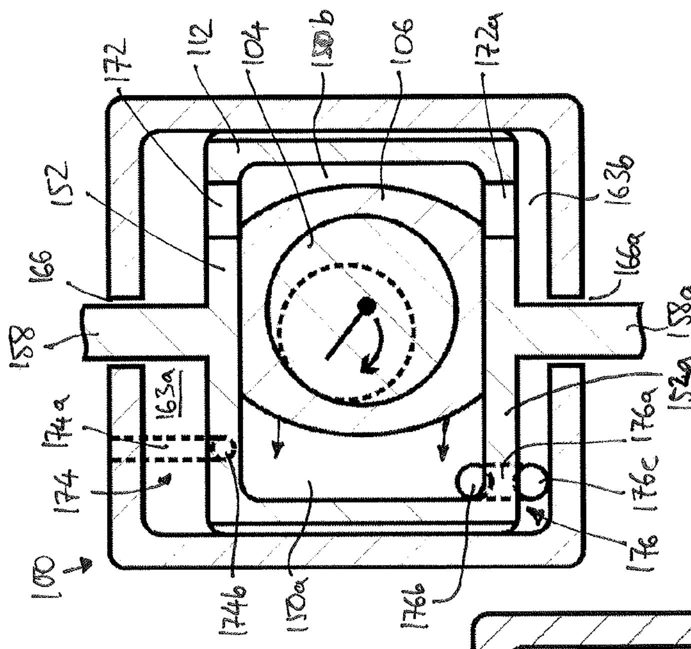

FIGURE 6(b)

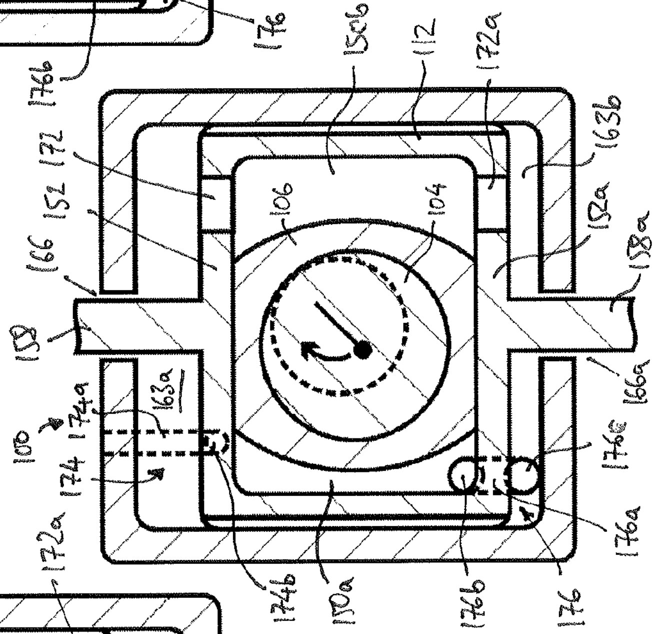

FIGURE 6(c)

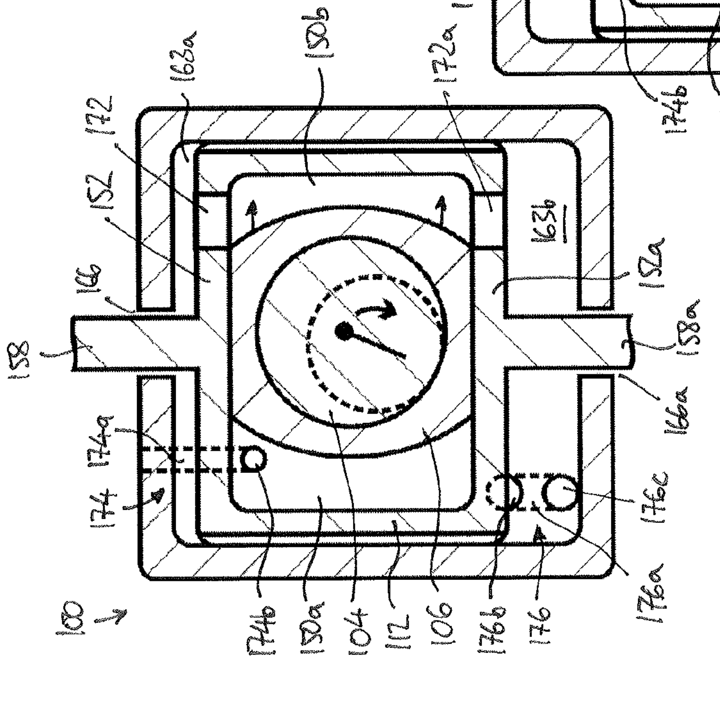

FIGURE 6(a)

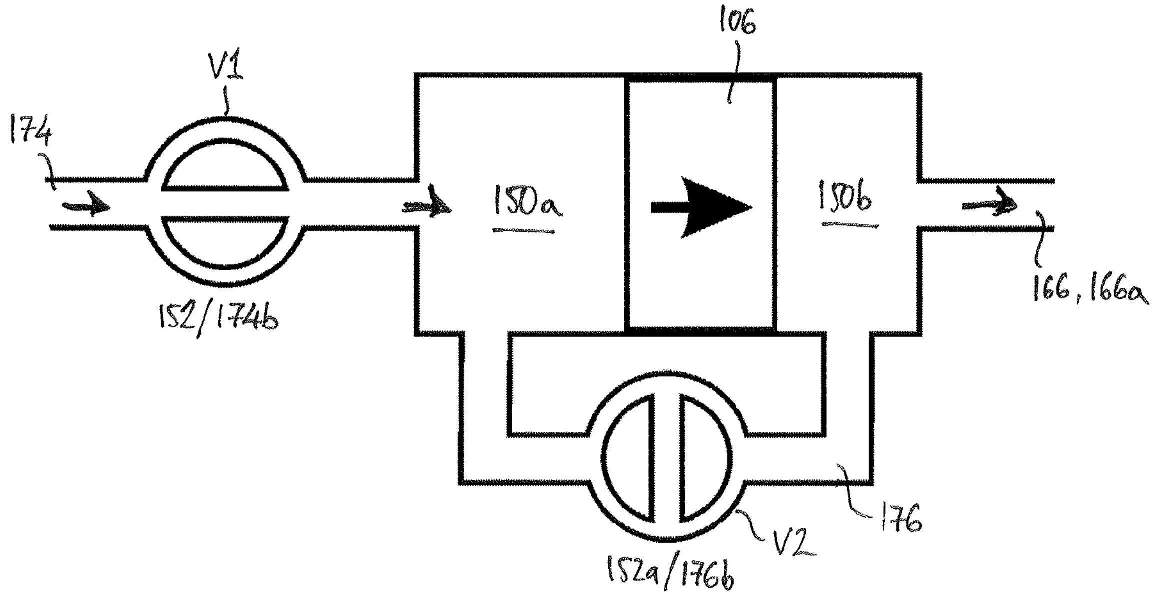

FIGURE 7(a)

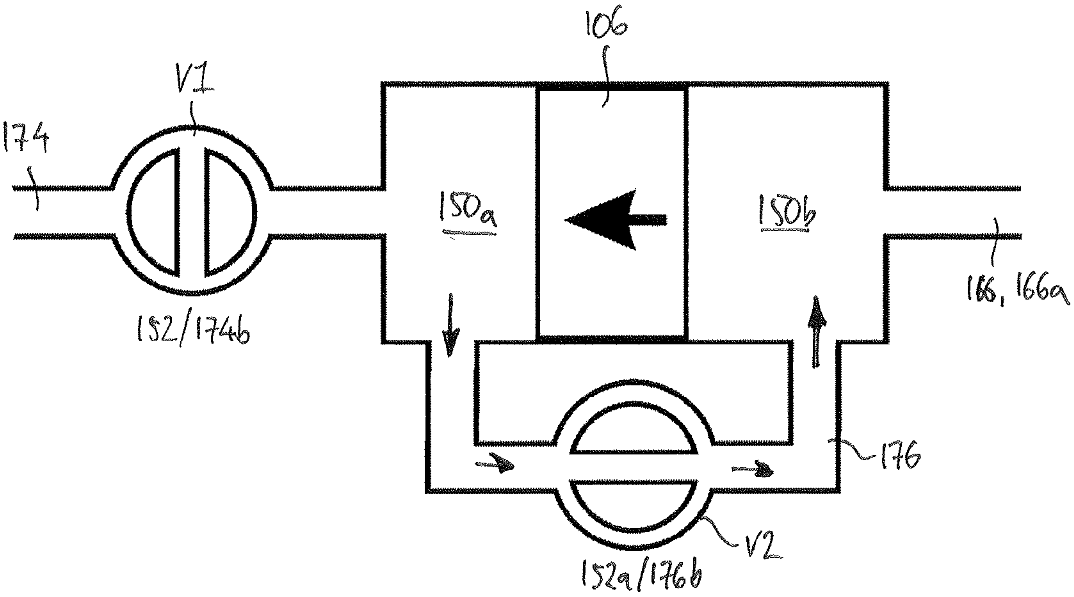

FIGURE 7(b)

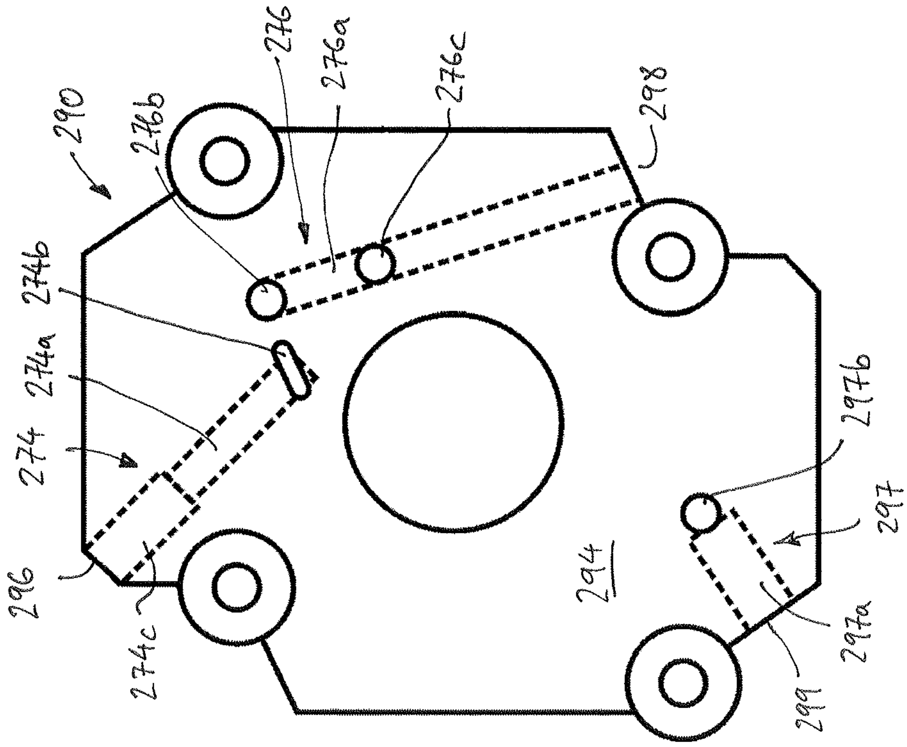

FIGURE 9

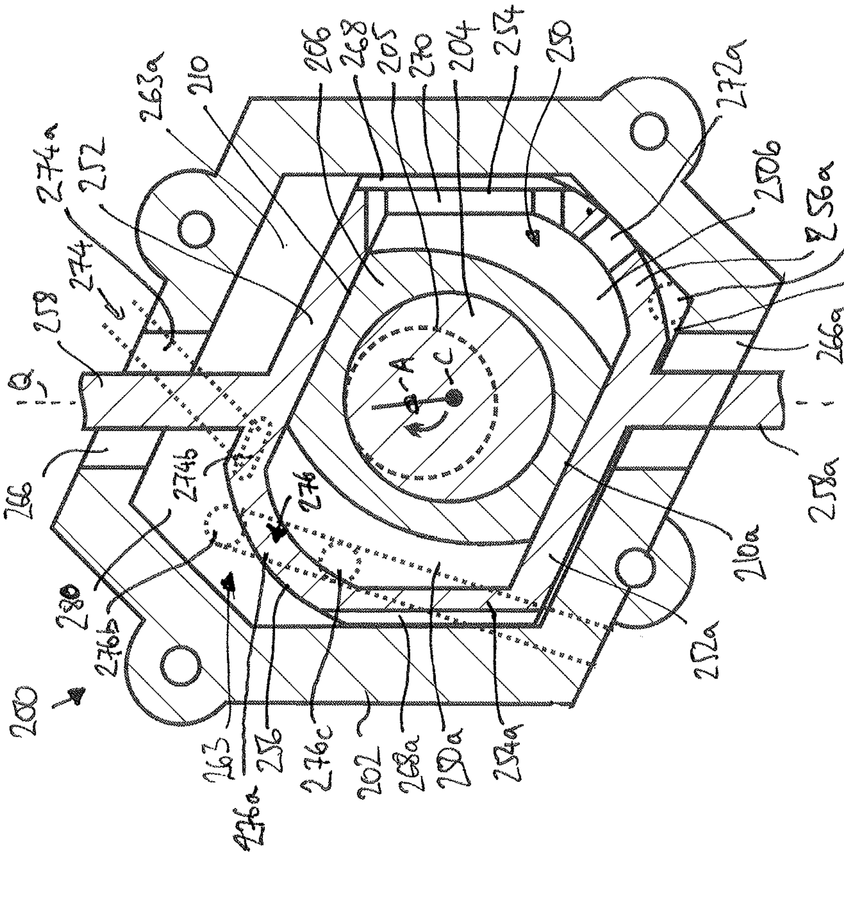

FIGURE 8

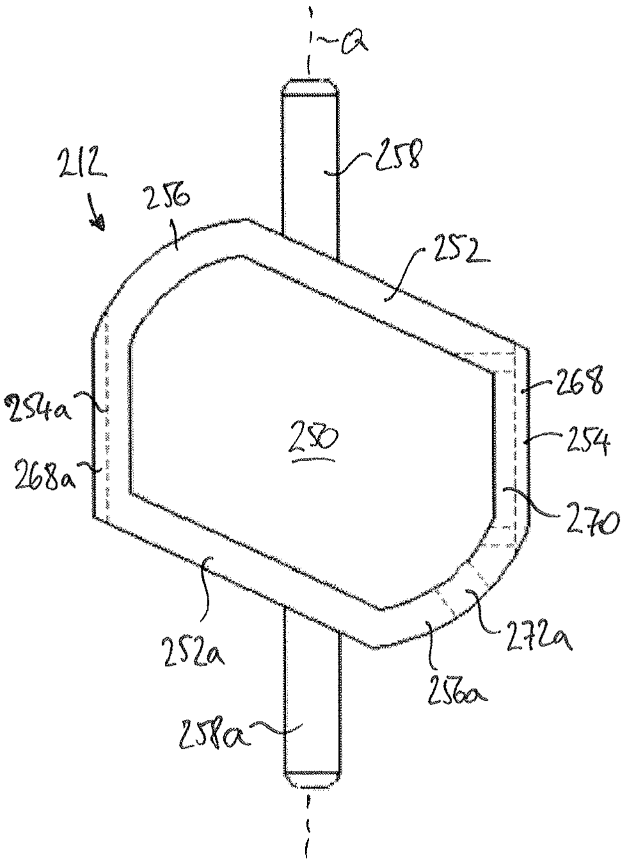

FIGURE 10(a)

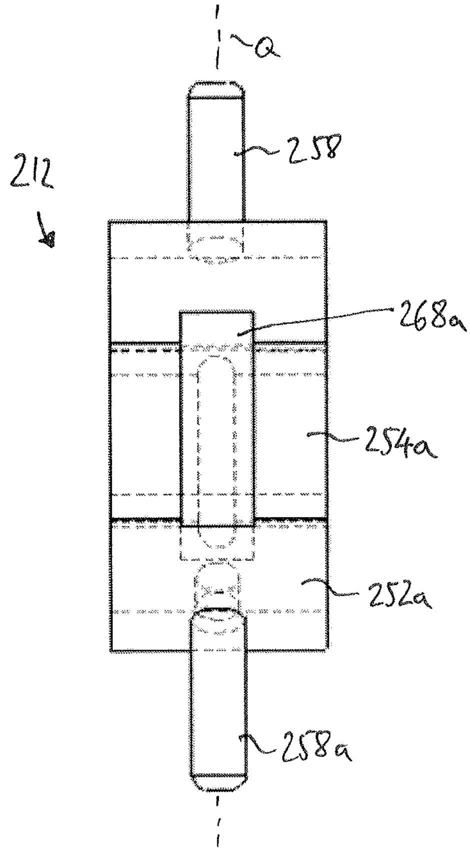

FIGURE 10(b)

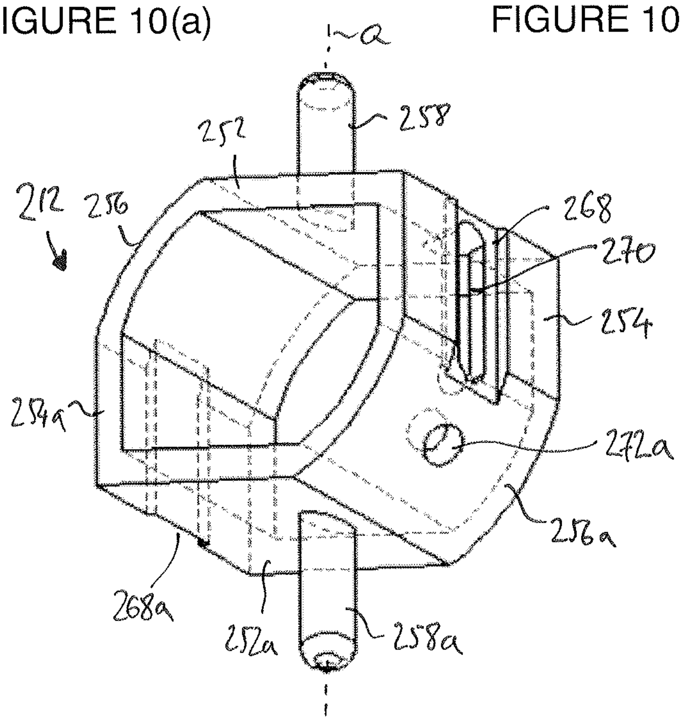

FIGURE 10(c)

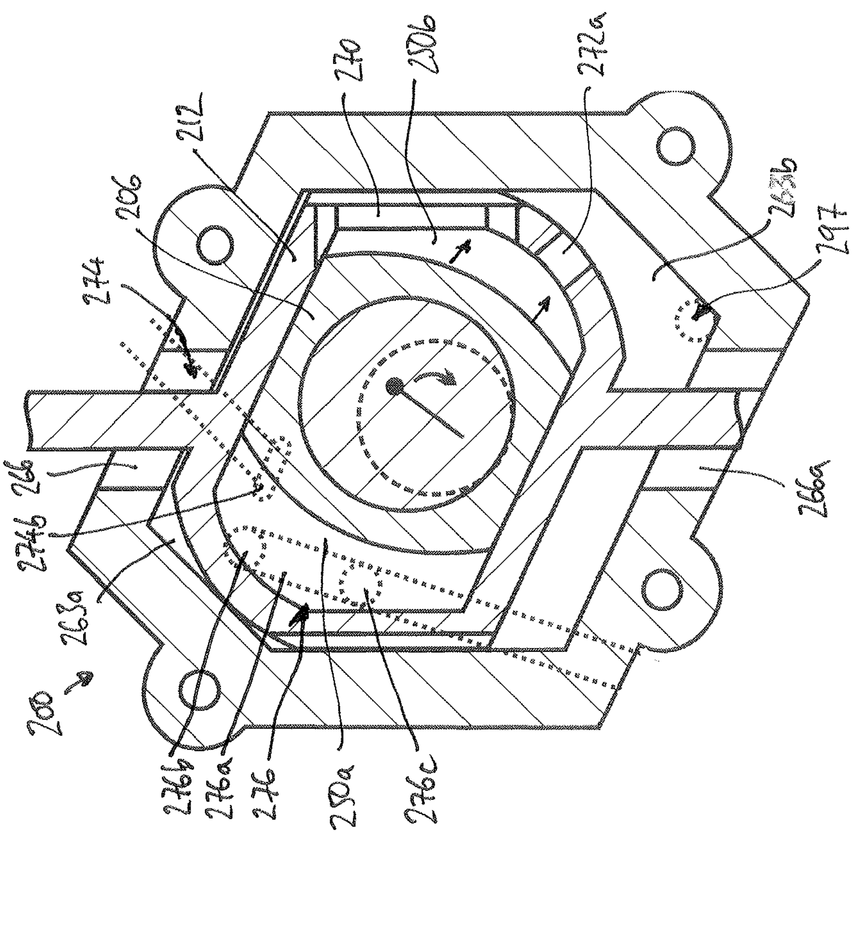

FIGURE 11(a)

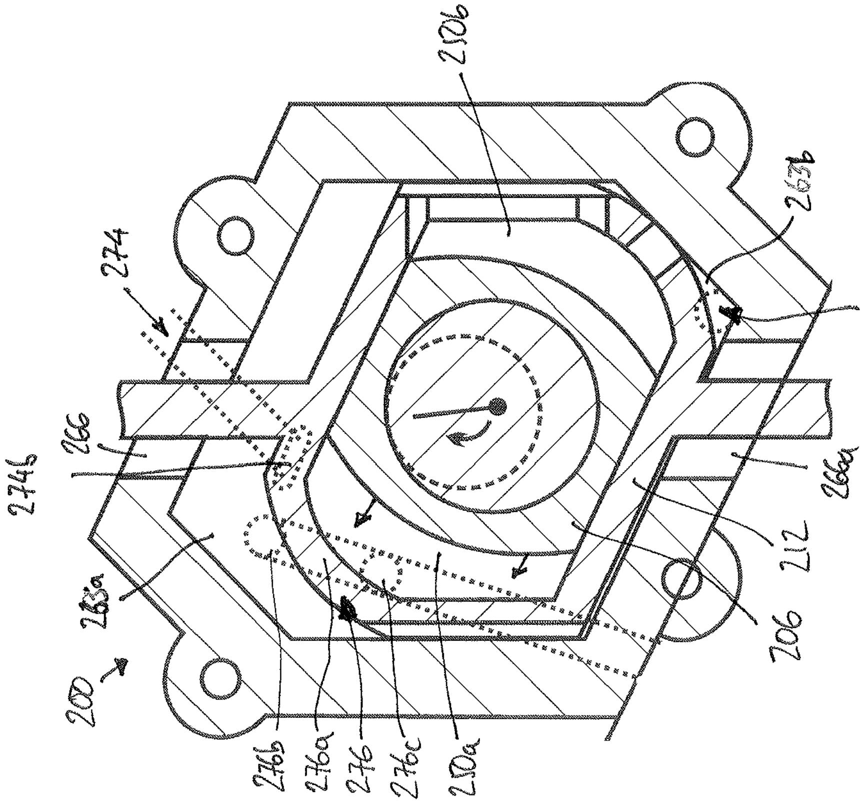

FIGURE 11(b)

Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 11 15 6278

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 2 013 862 A (SCHULZ ARTHUR E ET AL) 10 September 1935 (1935-09-10) * page 1, lines 1-5 * * page 4, column 1, line 13 - page 4, column 2, line 38; figure 16 * -----	1-15	INV. F04B7/04 F04B9/04 F04B3/00 F02M59/10
X	US 1 410 129 A (LOUIS SAUSSARD) 21 March 1922 (1922-03-21) * figures 6,7 * * page 2, lines 13-32 * * page 2, lines 94-113 * -----	1-15	
X	US 2 130 037 A (AXEL SKARLUND CARL) 13 September 1938 (1938-09-13) * figures 1,2,5,6,7 * * page 2, line 3 - page 3, line 41 * -----	1,3-6,9, 10,13-15	
X	US 968 126 A (CLARK WILLIAM) 23 August 1910 (1910-08-23) * figure 1 * * page 1, line 50 - page 2, line 76 * -----	1,3-6,9, 10,13-15	**TECHNICAL FIELDS SEARCHED (IPC)**
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	29 August 2011	Richmond, Robin

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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A : technological background
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L : document cited for other reasons
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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 11 15 6278

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
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29-08-2011

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US 1410129	A	21-03-1922	NONE	
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US 968126	A		NONE	
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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82