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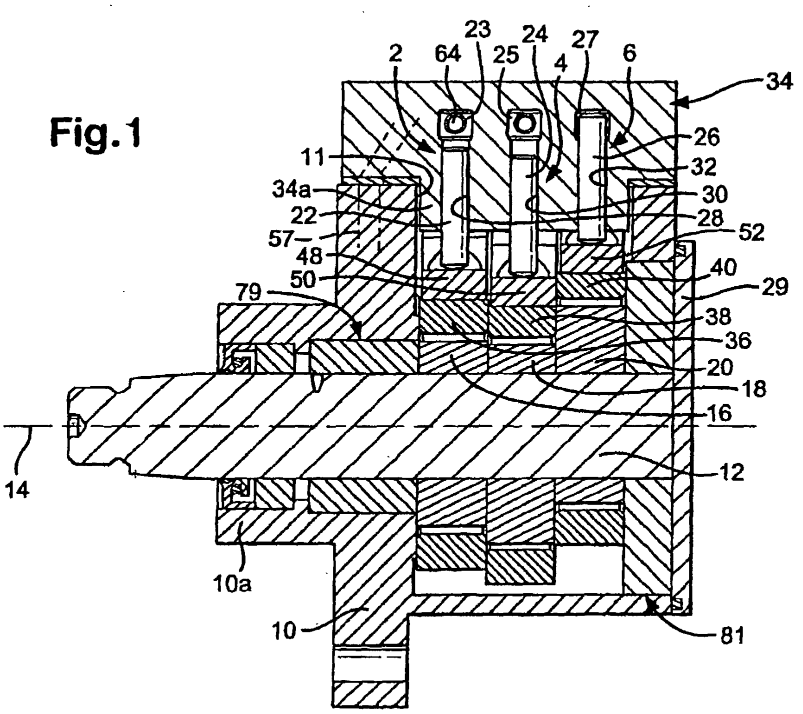
(54) Fuel pump

(57) A fuel pump for use in delivering fuel to a common rail of an internal combustion engine is described. The fuel pump comprises: at least first and second pump units (2,4,6) that are axially spaced along a camshaft (12) to form an in-line pump assembly, wherein each pump unit (2,4,6) includes a pumping plunger (22,24,26), a drive member (48,50,52) that is cooperable with the pumping plunger and driven, in use, by an associated cam arrangement (16,18,20) to impart drive to the plunger upon rotation of the camshaft, and a pump chamber (23,25,27) within which fuel is pressurised for delivery to the common rail. The pump chambers (23,25) of the first and second pump units (2,4) are arranged within a common pump head (34), which is mounted upon a main pump housing (10) having a main housing opening (13) through which the camshaft (12) extends. The pump head (34) defines a high pressure supply passage to which pressurised fuel is delivered from each of the pump chambers and from where pressurised fuel is supplied to the common rail, in use.

Fig. 1



EP 1 431 577 A1

Description

Technical Field

[0001] The invention relates to a fuel pump for use in a common rail fuel injection system for supplying high pressure fuel to a compression ignition internal combustion engine.

Background Art

[0002] In a known common rail fuel pump of radial pump design, for example as described in EP 1 184 568A, three pumping plungers are arranged at equi-angularly spaced locations around an engine driven cam. The surface of the cam cooperates with all three of the plungers, so that as the cam is driven each of the plungers is caused to reciprocate within a plunger bore to cause pressurisation of fuel within a respective pump chamber. The delivery of fuel from the pump chambers to a common high pressure supply line is controlled by means of respective delivery valves associated with each of the pumps. The high pressure line supplies fuel to a common rail, or other accumulator volume, for delivery to the downstream injectors of the common rail fuel system.

[0003] In one known fuel pump of the aforementioned type, each of the plungers is in connection with an associated tappet that serves to drive movement of the plunger within its bore. The cam carries a ring or rider that travels over the surface of the cam as it rotates to impart drive to the tappets, and hence to the plungers, causing the plungers to reciprocate in a phased, cyclical manner. The eccentricity of the cam surface causes each tappet, and its respective plunger, to be driven inwardly within its bore to reduce the volume of the pump chamber. During this forward, pumping stroke, fuel within the respective pumping chamber is pressurised to a relatively high level. The tappets are urged outwardly from the tappet bores by means of fluid pressure within a working chamber which, in addition to a force of a plunger return spring, serves to urge the plunger in an outward direction to perform a return stroke during which the pump chamber volume is increased.

[0004] The housing for pump arrangements of this type has three radially extending lobes, each for housing one of the plungers and its associated components. Such arrangements can be difficult to assemble and, in addition, require a relatively large accommodation space due to the radial layout of the plungers. In addition, due to the large radial separation between the three pump units, it is difficult to combine the high pressure flows from each pump chamber to a common high pressure outlet.

[0005] It is one object of the present invention to provide a fuel pump for use in a common rail fuel injection system, which alleviates or avoids at least one of the aforementioned problems.

Summary of the Invention

[0006] According to the present invention, there is provided a fuel pump for use in delivering fuel to a common rail of an internal combustion engine, comprising at least first and second pump units that are axially spaced along a camshaft to form an in-line pump assembly, wherein each pump unit includes a pumping plunger, a drive member that is cooperable with the pumping plunger and driven, in use, by an associated cam arrangement to impart drive to the plunger upon rotation of the camshaft, and a pump chamber within which fuel is pressurised for delivery to the common rail, wherein the pump chambers of the first and second pump units are arranged within a common pump head, which is mounted upon a main pump housing having a main housing opening through which the camshaft extends, and wherein the pump head defines a high pressure supply passage to which pressurised fuel is delivered from each of the pump chambers and from where pressurised fuel is supplied to the common rail, in use.

[0007] In a preferred embodiment of the invention the fuel pump includes first, second and third pump units of substantially similar form.

[0008] It is one advantage of the present invention that the plungers are mounted axially along a camshaft, and therefore the pump is relatively compact. The accommodation space required for the assembled pump is much less than that required for pumps of radial design, even when three pump units are provided, as the need for two radial lobes to house two of the plungers is avoided. The high accuracy requirement for angular spacing of the flats on the cam rider and the corresponding housing features, as in known radial pump designs, is also avoided.

[0009] As the overall length of the pump is much less than for known in-line pump designs, the pump has advantages of stability in the limited space available in current engine designs. By virtue of the compact design it is also possible to mount the pump within the engine such that the centre of mass of the pump is relatively close to the fixings to the engine, thereby reducing dynamic forces acting on, and deflection of, the pump due to engine vibration and road shocks.

[0010] It is a further advantage that the hydraulics required to connect the pump chambers to a common outlet or high pressure supply passage are simplified as all three pump chambers are closely spaced apart, preferably along an axis that is parallel to the axis of the camshaft.

[0011] The present invention requires only one component (the pump head) to withstand high fuel pressures, and the main pump housing is not exposed to highly pressurised fuel. There is also no requirement to transfer high pressure fuel across mating housing parts, as it is contained at all times within the pump head unit.

[0012] In a preferred embodiment, the pump head is provided with first, second and third plunger bores within which the pumping plunger of a respective one of the first, second and third pump units is movable. Preferably the first, second and third plunger bores are formed integrally in the pump head and the pump housing. The main pump head preferably includes an extension or projection that extends into the opening provided in the main pump housing, thereby to provide an increased length for provision of the first, second and third plunger bores. It is easy to form a projection on the pump head, and it provides the benefit that the sealing lengths of the plungers are relatively long so that leakage of high pressure fuel from the pump chambers is reduced.

[0013] In one embodiment, the main pump housing is provided with an additional opening or recess, preferably extending approximately laterally to the axis of the camshaft, said additional opening being shaped for cooperation with an outer surface of each of the drive members to guide axial movement of the drive members, but to substantially prevent lateral (i.e. lateral relative to the drive member axis) and angular movement thereof. In this case, the main pump housing is preferably formed from a material having good wear resistant properties, for example cast iron.

[0014] Preferably, the outer surface of each drive member is of part-cylindrical form. Advantageously, the main housing opening has a correspondingly shaped wall for cooperation with said part-cylindrical outer surfaces. The pump head has an underside for abutment with the main pump housing. Preferably, the inner surface of each drive member is also of part-cylindrical form. Preferably the outer walls have a greater degree of curvature than the inner walls, and the radius of the outer walls is preferably selected to be less than half the overall width of the drive member.

[0015] In one embodiment, the pump head may be shaped for cooperation with the outer surfaces of the drive members to guide axial movement of the drive members, throughout substantially a complete forward stroke of each drive member, but to substantially prevent lateral (i.e. lateral in a direction relative to the axis of the drive members) and angular movement of the drive members.

[0016] In this embodiment, the pump head may be provided with a skirt extension that is shaped for cooperation with the outer surfaces of the drive members to guide said axial movement thereof. Again, preferably, the outer surfaces of the drive members are of part-cylindrical form.

[0017] In a preferred embodiment, the drive member of each pump unit takes the form of a tappet that is cooperable, in use, with a cam ring rider of the associated cam arrangement to impart movement to the associated plunger upon rotation of the camshaft.

[0018] The pump head is preferably provided with first, second and third inlet supply passages for delivering fuel to the pump chambers of the first, second and third pump units respectively, wherein the inlet passages are arranged substantially parallel to each other and substantially perpendicular to the high pressure supply passage.

[0019] The fuel pump of the present invention may, but need not, be manufactured to include first, second and third cams arrangements for imparting drive to the pumping plungers.

[0020] If provided, the first and second cam arrangements preferably include first and second cams respectively that are integrally formed with the camshaft, and wherein the third cam arrangement includes a third cam that is a separate component, the first, second and third cams being arranged at axially spaced locations along the camshaft.

[0021] It will be appreciated, therefore, that references in this document to the first, second and cams being arranged on the camshaft, shall to taken to include the cams being integral with the shaft, or separate parts mounted upon the shaft.

[0022] It may be preferable to provide front and rear bearing journals, for example bearing tubes, on the camshaft to define first and second bearing surfaces respectively for a respective end one of the cams. The bearing journals may be integrally formed with the shaft, or may be separate parts forming an interference fit with the shaft.

[0023] The rear bearing journal preferably has a diameter greater than that of the front bearing journal, said rear bearing journal diameter being equal to or greater than the diameter of the main housing opening to permit direct mounting of the rear bearing journal upon, or support of the rear bearing journal by, the main housing.

[0024] In a further preferred embodiment, each of the first, second and third cam arrangements includes a cam rider member of tubular form that is driven, in use, by an associated one of the cams and which serves to impart drive to the associated drive member as it rides over the surface of the associated cam.

[0025] It will be appreciated that the fuel pump of the present invention is not limited to having three pump units, and a greater or lesser number of pump units may be provided, if required.

Brief Description of the Drawings

[0026] The present invention will now be described, by way of example only, with reference to the accompanying drawings in which:

Figure 1 is a sectional side view of a first embodiment of the fuel pump of the present invention;

Figure 2 is an end sectional view of the fuel pump shown in Figure 1;

Figure 3 is a perspective view of a main pump housing part of the fuel pump in Figures 1 and 2, with the pump head removed;

Figure 4a is a perspective view of a tappet forming part of the fuel pump in Figures 1 to 3;

Figure 4b is a plan view of the tappet shown in Figure 4a;

Figure 5 is a perspective view, shown from the underside, of the pump head for mounting upon the main pump housing shown in Figure 3;

Figure 6 is a perspective view of the assembled fuel pump illustrated in Figures 1 to 5, with the pump head mounted on the main pump housing;

Figure 7 illustrates a pump head forming part of an alternative embodiment of the fuel pump in which tappets of the pump are guided by the pump head, rather than by the main pump housing;

Figure 8 is a perspective view of a first type of cam arrangement for use with the fuel pump illustrated in Figures 1 to 7, in which two of the cams are formed integrally with the cam drive shaft; and

Figure 9 is a perspective view of a second type of cam arrangement for use in the fuel pump illustrated in Figures 1 to 7, in which the cams are separate from the cam drive shaft.

Detailed Description of the Preferred Embodiments

[0027] Referring to Figures 1 to 3, there is shown a fuel pump of a first embodiment for use in supplying high pressure fuel to a common rail, or accumulator volume, of a fuel injection system. The fuel pump includes a first housing part in the form of a main pump housing 10 having an axially extending main housing opening or bore 13 through which a cam drive shaft 12 extends. The main pump housing 10 projects, at its front end 10a, to accommodate the near full length of the camshaft 12, and is closed at its back end by a rear closure plate 29.

[0028] A second housing part in the form of a pump head or block 34 is a separate part from, and is mounted upon, the main pump housing 10, and extending laterally from the main housing opening 13 for the camshaft 12. The pump head 34 includes an extension or projection 34a that projects into an additional opening or aperture 11 provided in the main pump housing 10. The main pump housing 10 is provided with two ears 55 (visible in Figures 2 and 3 only), which act to stiffen the housing 10 around the opening 11.

[0029] The camshaft 12 has a central drive axis 14 about which the shaft 12 is driven, in use, to impart rotation to first, second and third cams, or cam forms, 16, 18, 20 of respective first, second and third cam arrangements. The cams 16, 18, 20 are arranged on the shaft 12 at axially spaced locations and oriented about the drive axis 14 at angularly offset locations. The first, second and third cams 16, 18, 20 are of substantially identical form and each one is mounted or formed eccentrically upon the camshaft 12 such that it is offset relative to the other two cams by substantially 120 degrees.

[0030] As the camshaft 12 is rotated, in use, the cams 16, 18, 20 impart drive to a respective one of first, second and third pumping plungers 22, 24, 26 so that motion of each plunger is phased by 120 degrees relative to the other two plungers. Each plunger 22, 24, 26 forms a part of one of three pump units 2, 4, 6 respectively that are axially spaced along the drive shaft 12 to form an "in-line" assembly. The three pump units 2,4, 6 are substantially identical in construction and, where possible for simplicity, only a first one of the pump units 2 will be described in detail. The pumping plunger 22, 24, 26 of each unit 2, 4, 6 is driven by its respective cam 16, 18, 20 to perform a pumping cycle. As the camshaft 12 rotates, each plunger 22, 24, 26 is caused to reciprocate within a respective plunger bore 28, 30, 32 provided in the pump head 34 so as to cause pressurisation of fuel within a respective pump chamber 23, 25, 27 defined by the blind end of the associated bore 28, 30, 32.

[0031] Each of the first, second and third cams 16, 18, 20 is arranged to cooperate with a respective cam rider 36, 38, 40 that, in turn, cooperates with a respective first, second or third drive member 48, 50, 52. The cam riders 36, 38, 40 are of substantially tubular form and are mounted relative to the shaft 12 with their axes parallel to the shaft axis 14. The drive members take the form of tappets 48, 50, 52, each of which is coupled to the associated plunger 22, 24, 26, such that as the shaft 12 rotates the cam riders 36, 38, 40 ride over the surface of the associated cam 16, 18, 20, imparting drive to the tappets 48, 50, 52, and hence to the plungers 22, 24, 26, to cause the plungers to reciprocate within the plunger bores 28, 30, 32.

[0032] As the camshaft 12 rotates, the tappets 48, 50, 52 and the pumping plungers 22, 24, 26 are together driven to perform a pumping or forward stroke, during which the tappet and its plunger are driven radially outward of the shaft 12 (i.e. vertically upwards in Figures 1 and 2) to reduce the volume of the associated pump chamber, followed by a return stroke during which the tappet and its plunger are urged in a radially inward direction (i.e. vertically downwards in Figures 1 and 2) to increase the volume of the pump chamber. During the return stroke of the plunger and its tappet, fuel at relatively low pressure fills the associated pump chamber and during the pumping stroke fuel within the pump chamber is pressurised to a relatively high level, as discussed further below.

[0033] Figure 2 illustrates an end sectional view of the pump, and in which only one of the plungers 22 and its associated tappet 48 are visible. It can be seen that the tappet 48 is of substantially U-shaped or channelled cross section, and includes a base portion 48a and first and second substantially vertical side portions or walls 48b. The lower surface (in the orientation shown) of the tappet base portion 48a engages with a flat 42 on the associated cam rider 36. The second and third tappets 50, 52 associated with the second and third plungers 24, 26 are of substantially identical form, having side walls 50b, 52b respectively (as shown in Figure 3), and for convenience only the features of the first tappet 48 are shown and described in detail below.

[0034] Referring also to Figure 4a, the upper surface of the tappet base portion 48a is provided with first and second recesses 60, 62 for locating a respective one of a first pair of plunger return springs 50a, 50b. The opposite end of each plunger return spring 50a, 50b abuts the pump head 34a, as shown in Figure 2. In this embodiment, the plunger 22 and the tappet 48 are not coupled together so as to permit relative movement between these parts during the pumping cycle. The plunger return springs 50a, 50b apply a return biasing force to the tappet 48, and hence to its plunger, to drive the plunger return stroke and to ensure contact is maintained between the tappet 48 and the cam rider 36 at all times throughout the pumping cycle. The base portion 48a of the tappet 48 is also provided with a centrally located boss 58 (also just visible in Figure 2) to limit the area for precision machining required to set the height of the plunger relative to the pump chamber 23.

[0035] Referring also to Figure 4b, the side walls 48b of the tappet 48 have outer surfaces 56 of part-cylindrical form of radius R1, and inner surfaces 59 also of part-cylindrical form. The outer surfaces 56 of the tappet side walls 48b are shaped so as to have a greater degree of curvature than the inner surfaces 59. More specifically, the radius, R1, of the outer surfaces 56 is selected to be less than the width, W, of the tappet, where W = 2 * R2, and R2 is the radius of the circle (shown by the dotted lines 51) which has the same degree of curvature as the inner surfaces 59 of the side walls 48b. Thus, the tappet 48 is not merely a right-circular cylinder with cut-away sides, but is specifically shaped and dimensioned so as to provide unwanted angular movement of the tappet, in use, about an axis aligned with the plunger axis. Although not visible in the sections shown, the second and third plungers 24, 26 are also provided with associated pairs of plunger return springs in a similar manner.

[0036] In an alternative embodiment (not shown in the accompanying drawings), the plunger 22 and the tappet 48 may be coupled together by means of a plate in connection with the lower end of the plunger 22. The plate may be secured to the plunger 22 by means of a clip, through an interference fit or through another integral projection or part thereof that co-operates with the plunger to provide a secure means of fixing. The plate locates within the side walls 48b of the tappet (as identified in Figure 3, for example) and provides a platform on either side of the plunger 22 to define an abutment surface for a respective one of the plunger return springs 50a, 50b. One side of the plate may be provided with appropriately shaped recesses, each for accommodating one end of the associated spring 50a, 50b. On the opposite side of the plate, a boss, for example, may be provided for cooperation with one of the recesses 60 or 62 on the facing side of the tappet 48. Cooperation between the tappet 48 and the plate in this way, and between the plunger and the tappet, serves to prevent unwanted rotation of the plate, in use.

[0037] Figure 3 shows the main pump housing 10 with the pump head 34 removed to illustrate the location of the tappets 48, 50, 52. The opening 11 in the pump housing 10 has facing side walls, each of which is shaped to define three regions of part-cylindrical form. Each of the total of six part-cylindrical wall regions is shaped to cooperate with a correspondingly formed outer surface of an associated one of the tappet side walls 48b, 50b, 52b. This cooperation of parts, and the shape and dimensions of the outer surfaces 56 of the tappet walls 48b, 50b, 52b, serves to guide movement of the tappets 48, 50, 52 in an axial direction (i.e. in the direction along the tappet axis, extending radially from the camshaft 12) over its stroke, but substantially prevents undesirable lateral and angular movement of the tappets 48, 50, 52. It can be seen from the location of the third tappet 52 in the view shown in Figure 3 that, in use, the tappets 48, 50, 52 are driven such that at the end of their forward strokes the tappet side walls 48b, 50b, 52b are caused to extend through the upper, open end of the opening 11 and into a clearance space 61 (visible in Figure 2) defined by a recess in the underside of the pump head 34.

[0038] Figure 5 shows the pump head 34 for mounting upon the main pump housing 10 in Figure 3. The view of the pump head 34 is from the underside, which abuts the upper surface of the main pump housing 10 when the pump is assembled. The surface of the underside of the pump head 34 is provided with recesses 54 having inner walls defining three regions of part-cylindrical form. Part way through the tappet forward stroke the tappets 48, 50, 52 project from the opening 11 in the main pump housing 10 (as shown in Figure 3), into the clearance space 61, although they do not contact the inner walls of the recesses 54.

[0039] When the pump head 34 is mounted upon the main pump housing 10, the part-cylindrical regions of the recesses 54 are generally in alignment with the part-cylindrical regions of the wall of the opening 11. The extension 34a on the pump head 34 is clearly shown in Figure 5 and, when the pump head 34 is mounted upon the main pump housing 10, the extension 34a extends between the plungers 22, 24, 26 and their return spring pairs 50a, 50b so as to provide an increased length for the plunger bores 28, 30, 32. By providing an increased length for the provision of the plunger bores 28, 30, 32, the sealing length of each plunger is increased and, thus, losses due to fuel leakage from the pump chambers 23, 25, 27 can be reduced. Figure 6 shows the fuel pump when assembled with the pump head 34 in Figure 5 mounted upon the main pump housing 10 in Figure 3.

[0040] Referring again to Figure 1, the first pump chamber 23 associated with the first plunger 22 communicates with an inlet supply passages 64 (also visible in Figure 6) that is provided in the pump head 34. Three inlet supply passages 64 are provided in total, one for each pump chamber 23, 25, 27, and each receives fuel from a relatively low pressure fuel source, for example a transfer pump. The inlet passages 64 are provided in the pump head 34 in a substantially parallel arrangement.

[0041] Each inlet passage 64 is provided with a respective inlet valve arrangement including an inlet valve 66 that is operable in response to the pressure difference between fuel in the inlet supply passage 64 and fuel within the respective pump chamber 23, 25, 27 to move between open and closed states. When an inlet valve 66 is in its open state, fuel is supplied through the inlet supply passage 64 to the pump chamber and when the inlet valve 66 is in its closed state the supply of fuel to the pump chamber is prevented.

[0042] Each pump chamber 23, 25, 27 also communicates with a respective high pressure delivery passage 68 provided in the pump head 34 for delivering fuel to the common rail. Each delivery passage 68 is provided with a delivery valve arrangement including a delivery valve 70 that is operable in response to the pressure difference between fuel in the) associated pump chamber and fuel in the delivery passage 68 to move between open and closed states. When a delivery valve 70 is in its open state, fuel is supplied from the pump chamber to the delivery passage 68, and hence to the common rail. When the delivery valve 70 is in its closed state the back flow of high pressure fuel from the common rail into the pump chamber 23 is prevented.

[0043] As can be seen in Figures 5 and 6, the pump head 34 is provided with a common high pressure supply passage 72, which is oriented substantially perpendicular to the inlet passages 64 and which extends axially from the rear of the pump. The high pressure supply passage 72 receives high pressure fuel from the delivery passages from each pump chamber 23, 25, 27 and supplies fuel from the pump to a downstream common rail or other accumulator volume for fuel.

[0044] The inlet and delivery valves 66, 70 are of known construction and further details may be found, for example, in our co-pending European patent application EP 1184568A2 and British patent application GB 2,384,529A. Pressurisation of fuel within the pump chambers occurs during the pumping stroke of the associated plunger, during the period for which both the inlet and delivery valves are closed. When fuel is pressurised to a level that is sufficient to open the delivery valve 70, pressurised fuel is supplied through the delivery passage to the common supply passage 72 and, hence, to the common rail.

[0045] During the return stroke of the plunger, fuel pressure downstream of the pump chamber 23 is higher than that within the pump chamber 23 and the delivery valve 70 is urged closed. During the period of the return stroke for which the inlet valve 66 is urged open, fuel at relatively low pressure is supplied to the pump chamber 23 through the inlet supply passage 64 ready for commencement of the following pumping stroke. This cycle of pumping is described in further detail in the aforementioned patent applications, and in any case would be familiar to those skilled in this field and so will not be described here in further detail.

[0046] The fuel pump shown in Figures 1 to 6 is intended for use with a low pressure fuel pump, such as a transfer pump, which delivers fuel to the inlet supply passages 64 provided in the pump head 34 through a common inlet passage 57 (shown in dashed lines in Figure 1). The common inlet passage 57 is provided with an inlet metering valve arrangement (also not shown) and is located towards the front end 10a of the main pump housing 10.

[0047] Although not illustrated in the accompanying drawings, it is convenient to mount the transfer pump upon the rear closure plate 29 of the main pump housing 10, and to drive the transfer pump by means of a shaft extension in connection with the camshaft 12. The transfer pump supplies fuel at transfer pressure to the common inlet passage 57 for delivery to the inlet passages 64 and, hence, to the pump chambers 23, 25, 27. In order to pass fuel to and from the transfer pump, a communication hole may be provided in each of the ears 55 of the main pump housing 10, one through which fuel is drawn into the transfer pump at the rear of the main pump housing 10 and one through which fuel is supplied from the transfer pump, to the inlet metering valve arrangement and then to the common inlet passage 57.

[0048] It is a particular advantage of the fuel pump of this embodiment that it is convenient to combine the high pressure fuel flow from each pump chamber 23, 25, 27 into the common high pressure supply passage 72 as all three of the pump chambers 23, 25, 27, and their corresponding delivery passages 68, are provided in the common pump head 34. This provides a benefit over known radial pump designs, where the pump chambers are angularly spaced around the shaft and, hence, the combining of three high pressure flows to a common supply passage is difficult to achieve. There is also a requirement for only the pump head 34 to be capable of withstanding the high pressures of fuel within the pump chambers 23, 25, 27, and the pump head component can be formed easily with the extension 34a for increasing the sealing lengths of the plungers.

[0049] It is a further advantage of the "in-line" pump unit assembly that the plunger stroke length is comparable to that achieved in known radial pump designs, but the height of the assembled pump above the axis 14 of the camshaft 12 is moderate, and the overall height of the pump is much less than in radial pump designs. Essentially, the reduced height is achieved by avoiding the need for an extended protrusion of two pump units beneath the camshaft axis 14, as in known radial pump designs. The requirement for extremely accurate angular spacing of the flats on the cam rider, and the corresponding housing features, in a radial pump design is also avoided.

[0050] In the embodiment of the fuel pump described previously, the main pump housing 10 is typically formed from cast iron. The use of a cast iron housing 10 is beneficial in that it helps to limit wear of the tappets 48, 50, 52, in use, as their movement is guided along the vertical tappet axis through cooperation with the part-cylindrical regions in the wall of the opening 11. The wear resistant properties of cast iron stem from the high carbon content, which acts as a solid lubricant.

[0051] In an alternative embodiment of the pump to that described with reference to Figures 1 to 6, the requirement to form the main pump housing 10 from cast iron can be avoided by guiding movement of the tappets not by the wall of the opening 11 in the main pump housing 10 but through cooperation with a part of the pump head. This alternative embodiment is shown in Figure 7, and only the differences between this and the embodiment of Figures 1 to 6 will be described in detail, with similar and identical parts numbered with like reference numerals.

[0052] Referring to Figure 7, the pump head 134 is provided with a skirt extension 75 forming an additional extension from the underside of the pump head 134 and enclosing the extension 34a. In this embodiment, the opening 11 in the main pump housing 10 is formed with substantially straight walls (not illustrated in Figure 7), rather than providing the part-cylindrical wall regions. When the pump head 134 is mounted upon the main pump housing 10, the skirt extension 75 and the extension 34a are received within the opening 11, and the straight walls of the opening 11 in the main pump housing 10 align with outer straight walls 78 of the skirt 75 to locate the pump head 134. The skirt extension 75 has an inwardly facing surface 80 that is provided with regions of part-cylindrical form for cooperation with the correspondingly formed part-cylindrical outer surfaces of the tappet side walls 48b, 50b, 52b. The skirt extension 75 therefore serves to guide movement of the tappets 48, 50, 52 in an axial direction (i.e. in the direction along the tappet axis, extending radially from the camshaft 12), but prevents undesirable lateral and angular movement thereof.

[0053] The wear resistant properties of case hardened alloy steel, from which the pump head 134 is formed, are superior to those of cast iron. Furthermore, as the wear resistant requirement for the main pump housing 10 is removed, the main pump housing 10 may be formed from aluminium, for example, rather than cast iron. This provides a manufacturing advantage as a cheaper and more accurate process can be used to form the housing 10, for example die casting.

[0054] It will be appreciated that a difference between the pump head 34 in Figure 5 and the pump head 134 in Figure 7 is that in the Figure 5 embodiment the pump head 34 plays no part in guiding the tappets 48, 50, 52 as the tappets, 48, 50, 52 project from the main pump housing 10 into the clearance space 61 at the end of their forward strokes and at the start of their return strokes. In contrast, in the embodiment of Figure 7 movement of the tappets 48, 50, 52 is guided through cooperation with the pump head skirt 75 throughout substantially the complete pumping stroke. The embodiment of Figure 7 also provides all of the aforementioned advantages of the first embodiment of the invention.

[0055] Referring in particular to Figure 2, and also to Figure 8, the outer surface of each cam rider 36, 38, 40 is provided with a flat 42, 44, 46 respectively (only cam rider 38 is shown in Figure 8). By way of example, the flat 42 on the first cam rider 36 is engaged with the tappet 48 coupled to the first plunger 22. The cam riders 38, 40 for the second and third units 4, 6 are arranged in a similar manner.

[0056] The second and third cams 18, 20 are formed integrally with the shaft 12, but as it is difficult to machine all three cams 16, 18, 20 to be integral with the shaft 12 the first cam 20 is a separate part. The first cam 16 forms an interference fit with the shaft 12 and is of larger diameter than the third cam 20 so that, upon assembly, the shaft is able to pass through it while retaining enough strength in the cam 16 to implement the required interference fit.

[0057] Front and rear bearing journals (the rear bearing journal 76 only being visible in Figure 9) may be mounted on the shaft 12 so that the front bearing journal 74 abuts against the first cam 16 and the rear bearing journal 76 abuts against the third cam 20. The bearing journals form an interference fit with the shaft 12 and serve to 'trap' the first and third cam riders 36, 40 in position. The bearing journals are capable of achieving high peripheral speeds and are selected to have a relatively large diameter so as to provide extra area per unit length of the shaft and, thus, provide support for high camshaft loads. The bearing journals thus provide plain bearing journal regions of increased area (defined by their axial length and their diameter) and, hence, load-bearing capability.

[0058] In an alternative embodiment, as shown in Figure 9, all three of the cams 16, 18, 20 are substantially identical components separate from the shaft 12 and mounted thereon by means of an interference fit. The cam riders 36, 38, 40 are mounted upon their respective cams 16, 18, 20 with the second, middle cam rider 38 being trapped between the first and third cam riders 36, 40. In this embodiment both front and rear bearing journals 74, 76 are visible, with the first bearing journal 74 abutting against the first cam 16 and the second bearing journal 76 abutting against the third cam 20.

[0059] The axial length of the rear bearing journal 76 (i.e. the length of the journal 76 along the axis of the shaft 12) is less than that of the front bearing journal 74 so as to limit the overall axial length of the assembly. Although not illustrated in the accompanying drawings, the diameter of the rear bearing journal 76 is selected to be equal to or greater than the diameter of the main housing bore 13 to enable the journal 76 to be supported by or mounted upon the housing 10 without a requirement for an intermediate component or components.

[0060] It is an advantage of the embodiment in Figure 9 that the shaft 12 is of simple rod-like construction, with appropriate end features in the form of bearing journals 74, 76, thus facilitating convenient and economical manufacture. It is a further advantage of the fuel pump of the present invention that the over all length of the assembly is much less than is known for in-line pump designs. The pump therefore has advantages of instability in the limited space available in current engine designs. By virtue of its compact design it is possible to mount the pump within the engine such that the pump centre of mass is relatively close to that part which fixes to the engine (e.g. the ears 55 shown in Figure 1). The pump does not therefore suffer excessive dynamic forces and deflection caused by engine vibration and road shocks.

[0061] To aid assembly of the cam, bearing journals and cam ring riders on the camshaft, it is convenient to use a temporary tool, such as a rod, that extends through the openings of these components. The rod is a close fit with the openings and serves to locate the components in their correct angular and axial positions relative to the shaft, prior to insertion of the camshaft, which when inserted forms an interference fit in the openings and supports the aforementioned parts.

[0062] If a cast iron housing 10, first and second static bearing surfaces 79, 81 (identified in Figure 1) for the front and rear bearing journals 74, 76 respectively may be cut directly into the front end 10a of the main pump housing 10, therefore avoiding the need to provide additional bearing support bushes for the journals. The pump head 34 is typically formed from case hardened alloy steel.

[0063] It will be appreciated that the use of the phrase "common rail" is not intended to be in any way limiting, and that the fuel pump described in this document may be used for delivering fuel to any form of accumulator volume or store for pressurised fuel, from where fuel is subsequently supplied to injectors of an associated engine.

Claims

1. A fuel pump for use in delivering fuel to a common rail of an internal combustion engine, the fuel pump comprising:

    at least first and second pump units (2,4,6) that are axially spaced along a camshaft (12) to form an in-line pump assembly, wherein each pump unit includes a pumping plunger (22,24,26), a drive member (48,50,52) that is cooperable with the pumping plunger and driven, in use, by an associated cam arrangement (16,18,20) to impart drive to the plunger upon rotation of the camshaft, and a pump chamber (23,25,27) within which fuel is pressurised for delivery to the common rail,

    wherein the pump chambers (23,25) of the first and second pump units (2,4) are arranged within a common pump head (34), which is mounted upon a main pump housing (10) having a main housing opening (13) through which the camshaft extends (12), and wherein the pump head defines a high pressure supply passage to which pressurised fuel is delivered from each of the pump chambers and from where pressurised fuel is supplied to the common rail, in use.

2. A fuel pump as claimed in Claim 1, including first, second and third pump units (2,4,6) spaced axially along the camshaft (12).

3. A fuel pump as claimed in Claim 2, wherein the pump head (34) is provided with first, second and third plunger bores (28,30,32) within which the pumping plunger (22,24,26) of a respective one of the first, second and third pump units (2,4,6) is movable.

4. A fuel pump as claimed in Claim 3, wherein the main pump housing (10) is provided with an additional opening (11) and the pump head includes a projection (34a) that extends into the additional opening, thereby to provide an increased length for the first, second and third plunger bores (28,30,32).

5. A fuel pump as claimed in Claim 3 or Claim 4, wherein the main housing opening (13) is shaped for cooperation with an outer surface 56 of each of the drive members (48,50,52) to guide axial movement of the drive members, but to substantially prevent lateral and angular movement thereof.

6. A fuel pump as claimed in Claim 4 or Claim 5, wherein the outer surface 56 of each drive member (48,50,52) is of part-cylindrical form, and wherein the additional opening (11) in the main pump housing (34) has a correspondingly shaped wall for cooperation with said part-cylindrical outer surfaces 56.

7. A fuel pump as claimed in any of Claims 1 to 4, wherein the pump head (34) is shaped for cooperation with an outer surface 56 of each of the drive members (48,50,52) to guide axial movement of the drive members throughout substantially a complete forward stroke of each drive member, but to substantially prevent lateral and angular movement of the drive members.

8. A fuel pump as claimed in Claim 7, wherein the pump head (34) is provided with a skirt extension (75) that is shaped for cooperation with the outer surfaces 56 of the drive members (48,50,52) to guide said axial movement thereof.

9. A fuel pump as claimed in Claim 7 or Claim 8, wherein the outer surfaces 56 of the drive members (48,50,52) are of part-cylindrical form.

10. A fuel pump as claimed in any of Claims 5 to 9, wherein the outer surfaces 56 of the drive members (48,50,52) are of part-cylindrical form of radius R1, where R1 is less than half the width, W, of the drive member.

11. A fuel pump as claimed in any one of Claims 1 to 10, wherein the drive member (48,50,52) of each pump unit takes the form of a tappet that is cooperable, in use, with a cam ring rider (36,38,40) of the associated cam arrangement (16,18,20) to impart movement to the associated plunger (22,24,26) upon rotation of the camshaft (12).

12. A fuel pump as claimed in any one of Claims 1 to 11, wherein the pump head (34) is provided with at least first and second inlet supply passages (64) for delivering fuel to the pump chambers (23,25) of the first and second pump units (2,4), wherein the inlet passages are arranged substantially parallel to each other and substantially perpendicular to the high pressure supply passage (68).

13. A fuel pump as claimed in any of Claims 1 to 12, including at least first and second cam arrangements (16,18) for imparting drive to the pumping plunger (22,24) of the associated first and second pump unit (2,4), the first and second cam arrangements being axially spaced along the camshaft (12).

14. A fuel pump as claimed in Claim 13, including first, second and third cam arrangements including first, second and third cams (16,18,20), wherein the first and second cams (16,18) are integrally formed with the camshaft (12) and the third cam (20) is a separate component, the first, second and third cams (16,18,20) being arranged axially along the camshaft (12).

15. A fuel pump as claimed in Claim 14, wherein front (74) and rear (76) bearing journals are provided on the camshaft (12) in an interference fit to define first and second bearing surfaces respectively for a respective end one of the cams (16,18,20).

16. A fuel pump as claimed in Claim 15, wherein the rear bearing journal (76) has a diameter greater than that of the front bearing journal (74), said rear bearing journal diameter being equal to or greater than the diameter of the main housing opening (13) to permit direct mounting of the rear bearing journal (76) upon, or support of the rear bearing journal by, the main housing.

17. A fuel pump as claimed in any one of Claims 14 to 16, wherein each of the first, second and third cam arrangements includes a cam rider member (36,38,40) of tubular form that is driven, in use, by the associated one of the cams (16,18,20) and which serves to impart drive to the associated drive member (48,50,52) as it rides over the surface of the associated cam.

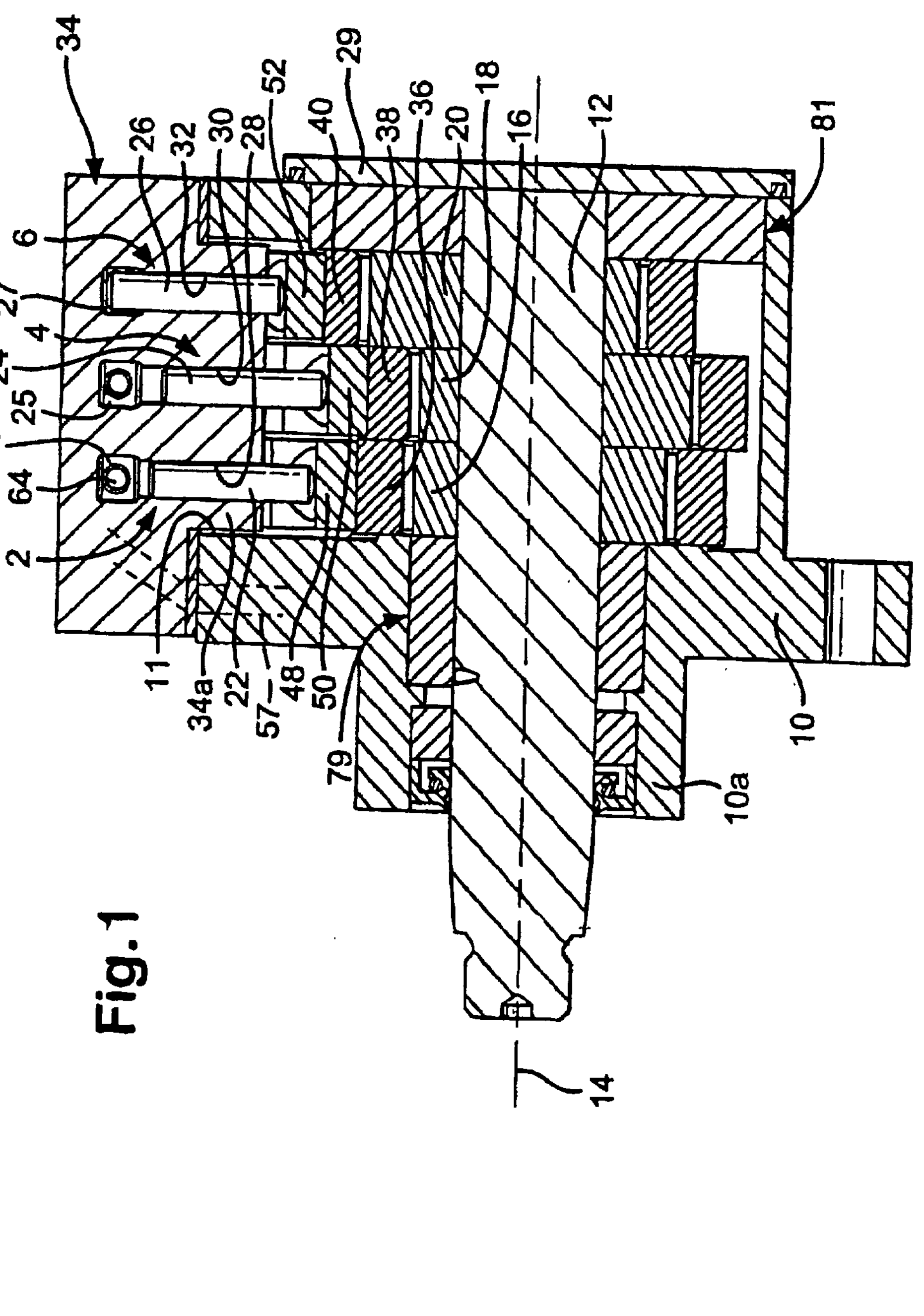

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Fig.1

Fig.2

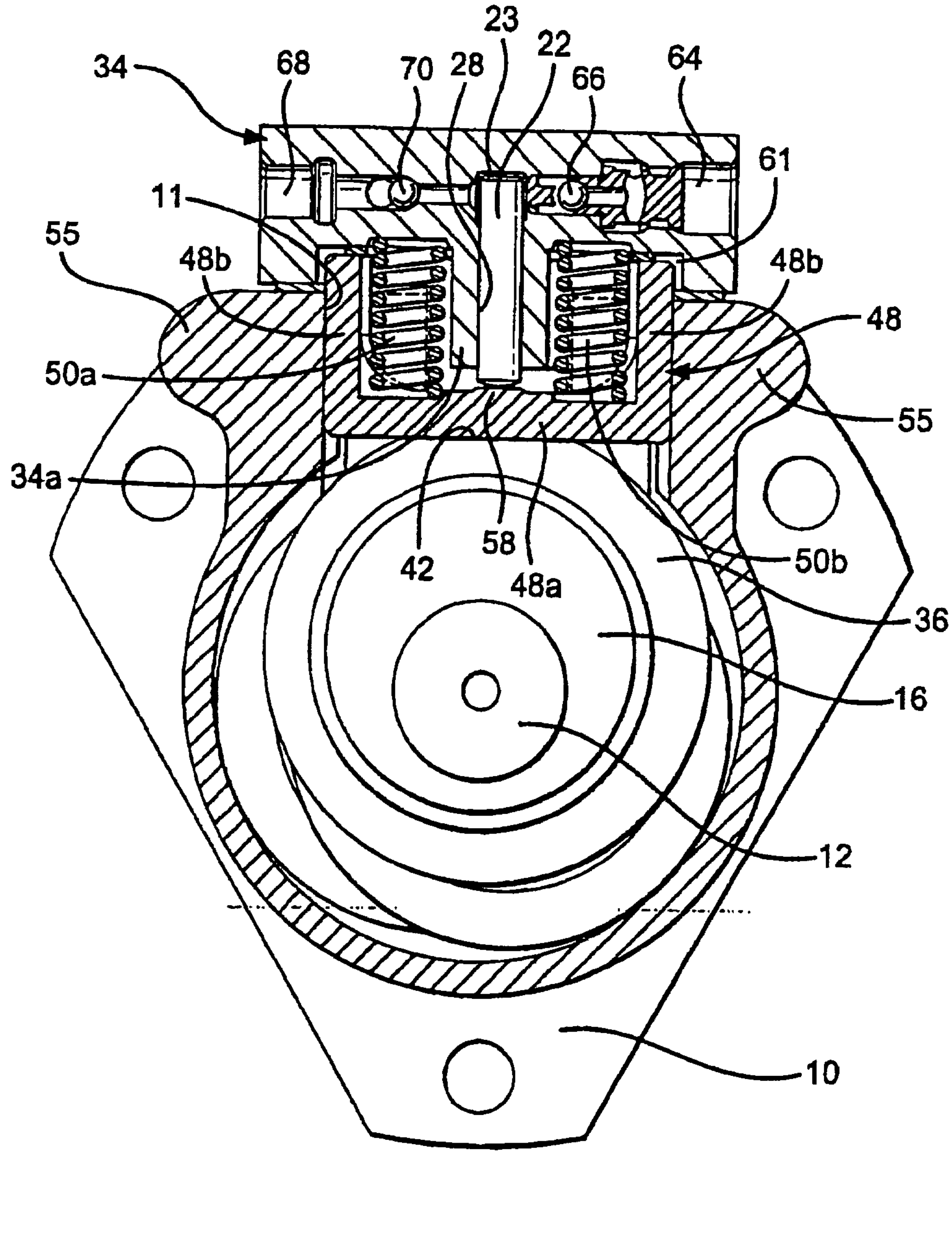
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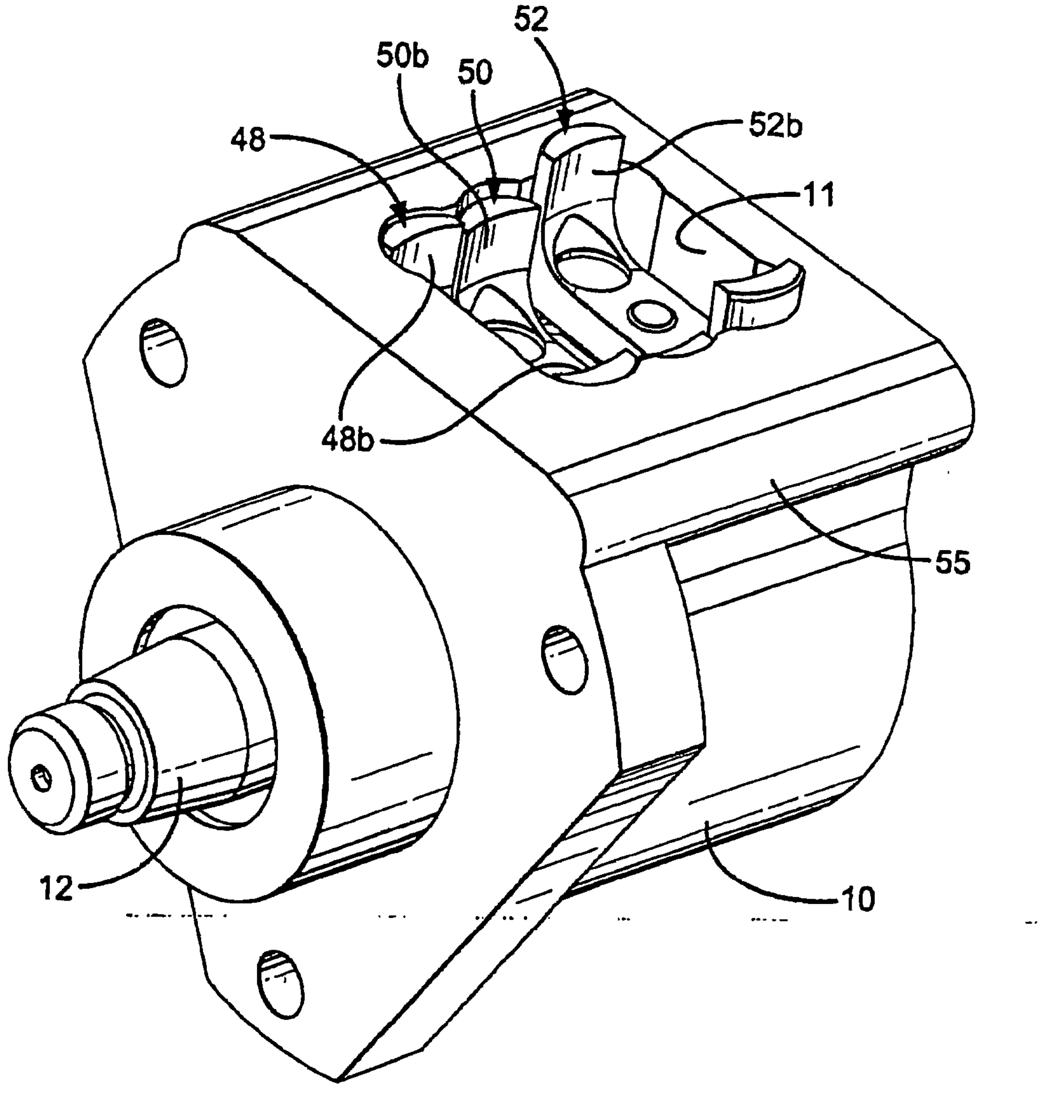
Fig.3



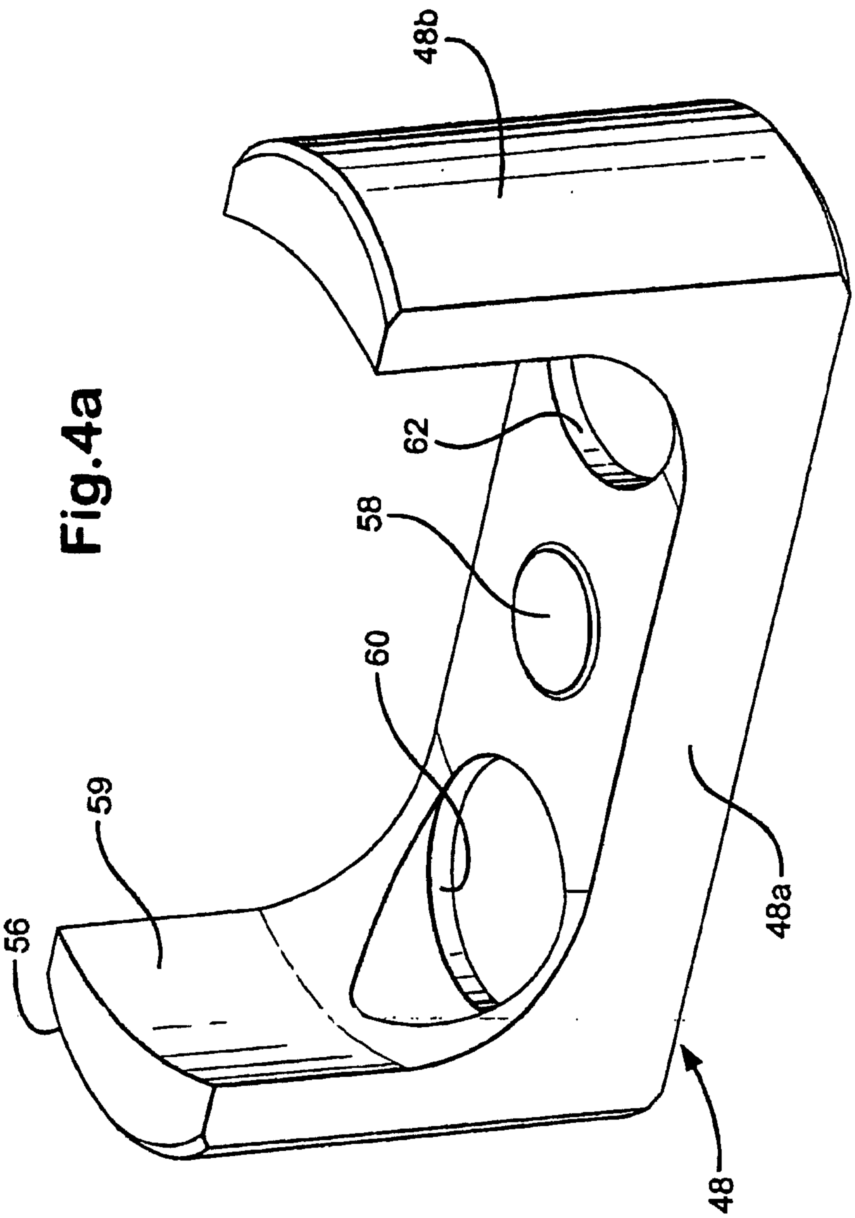
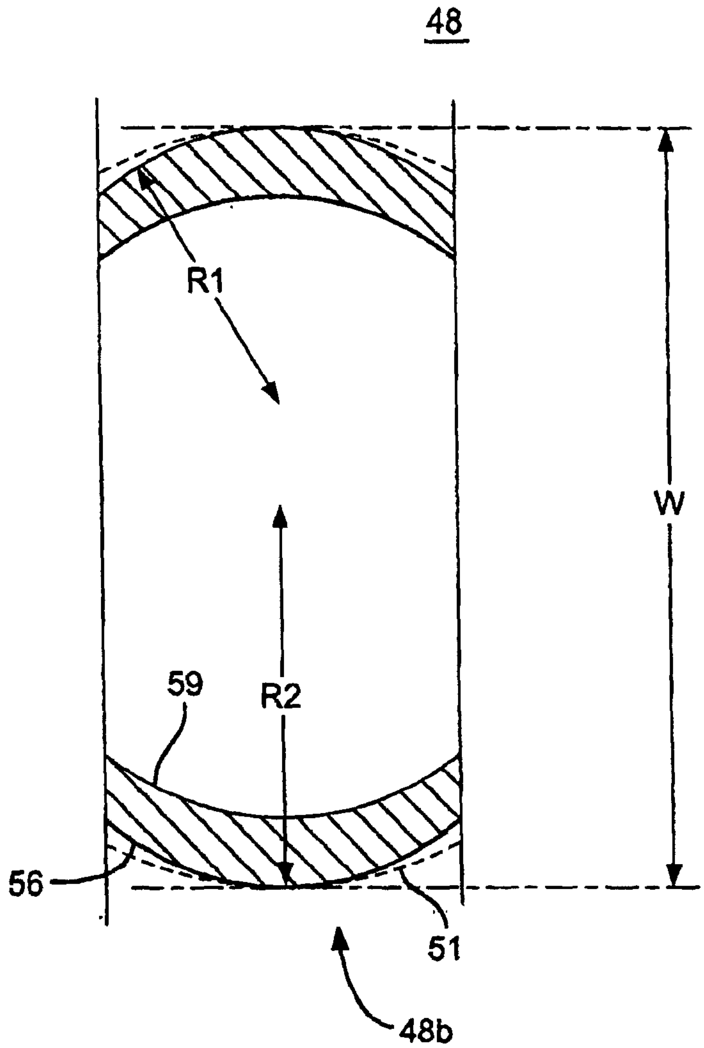


Fig.4a

Fig.4b



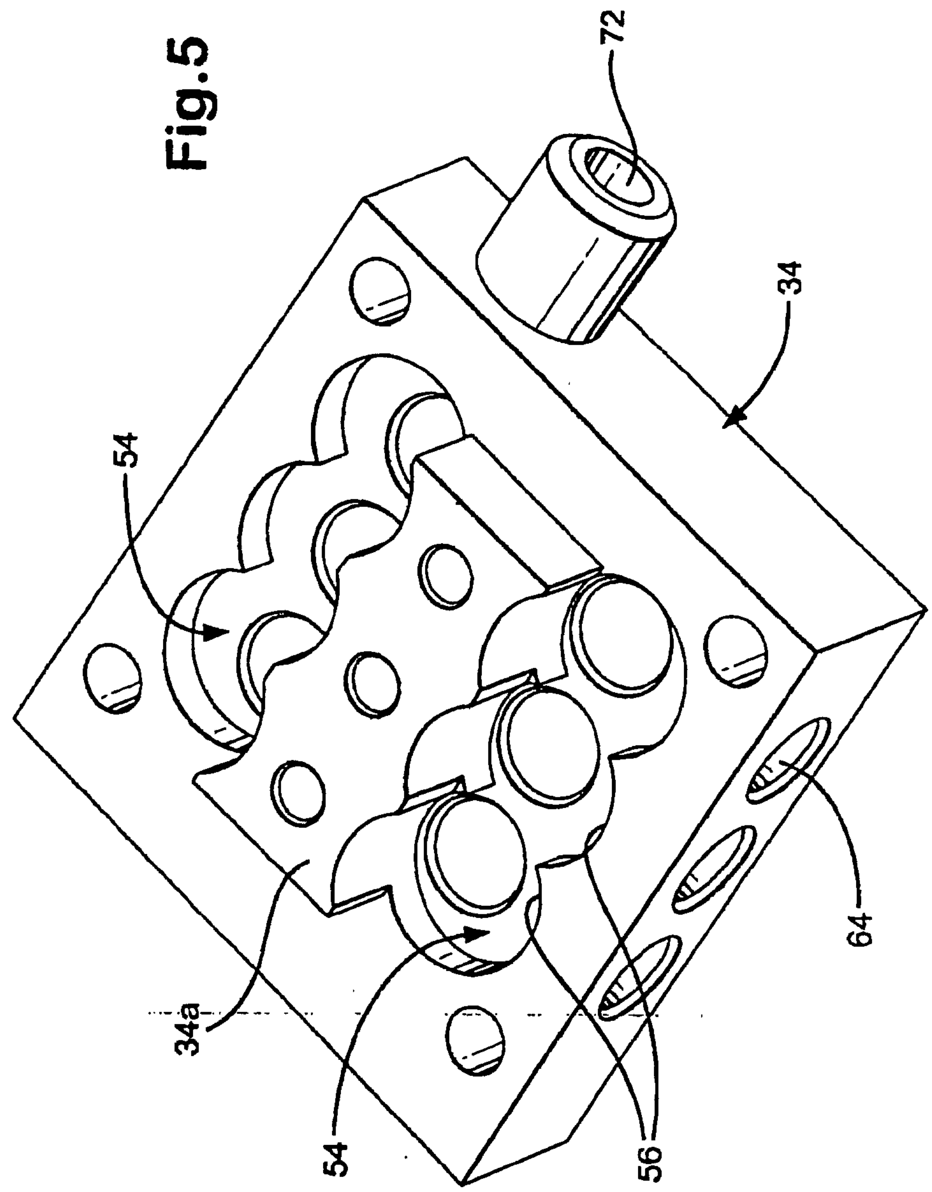


Fig.5

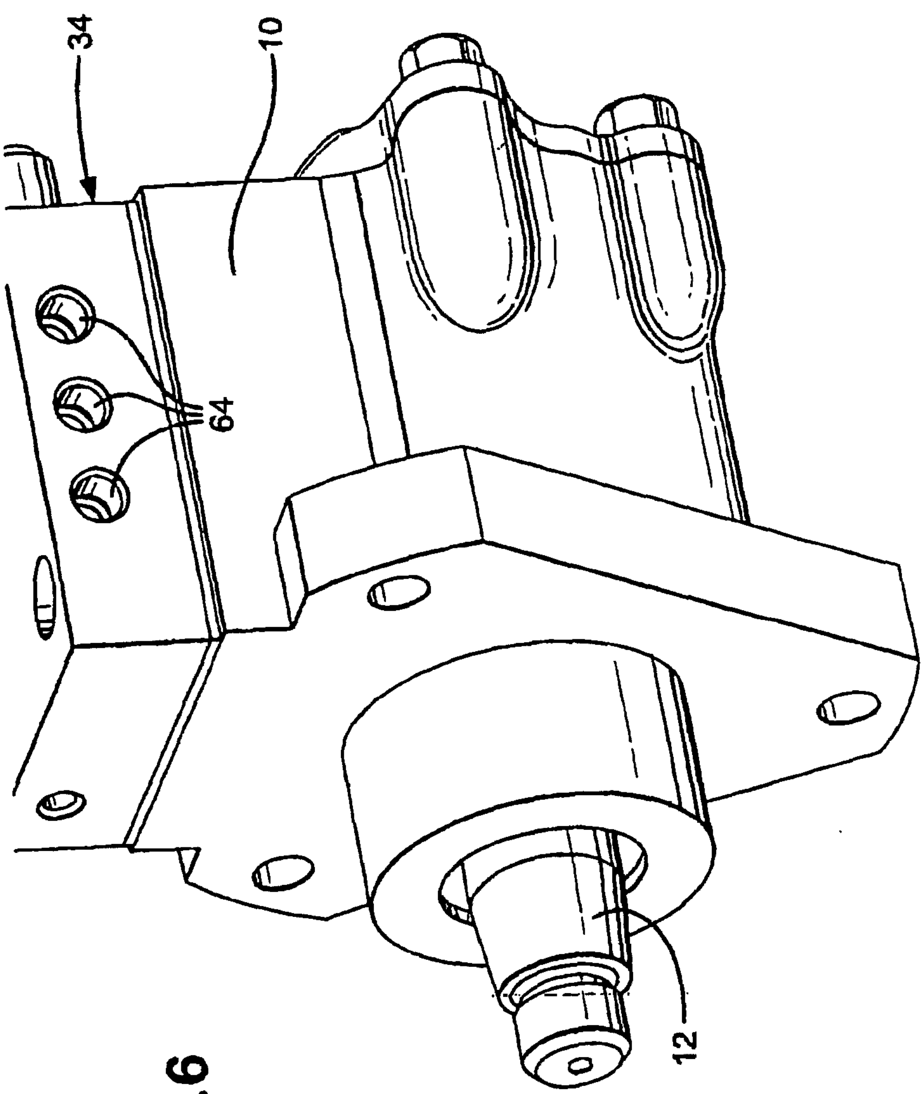


Fig.6

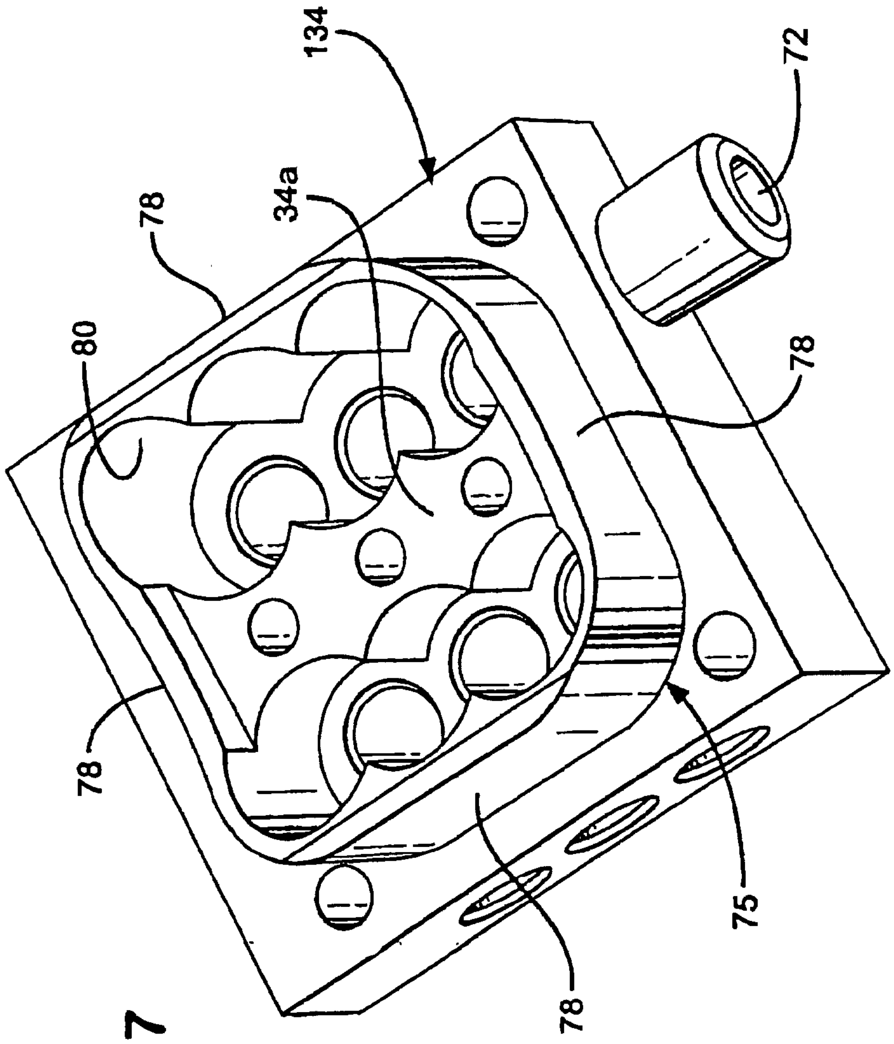


Fig.7

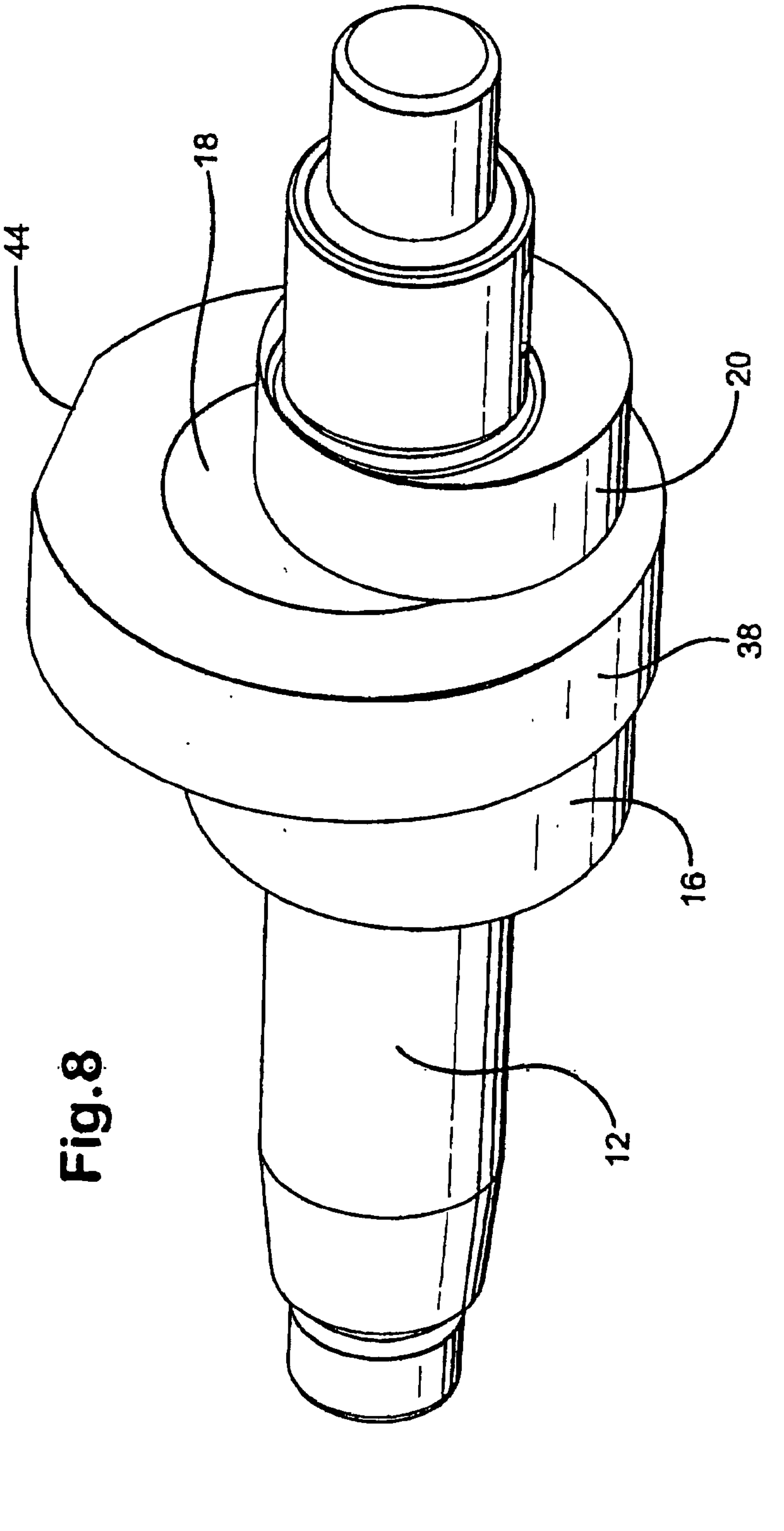


Fig.8

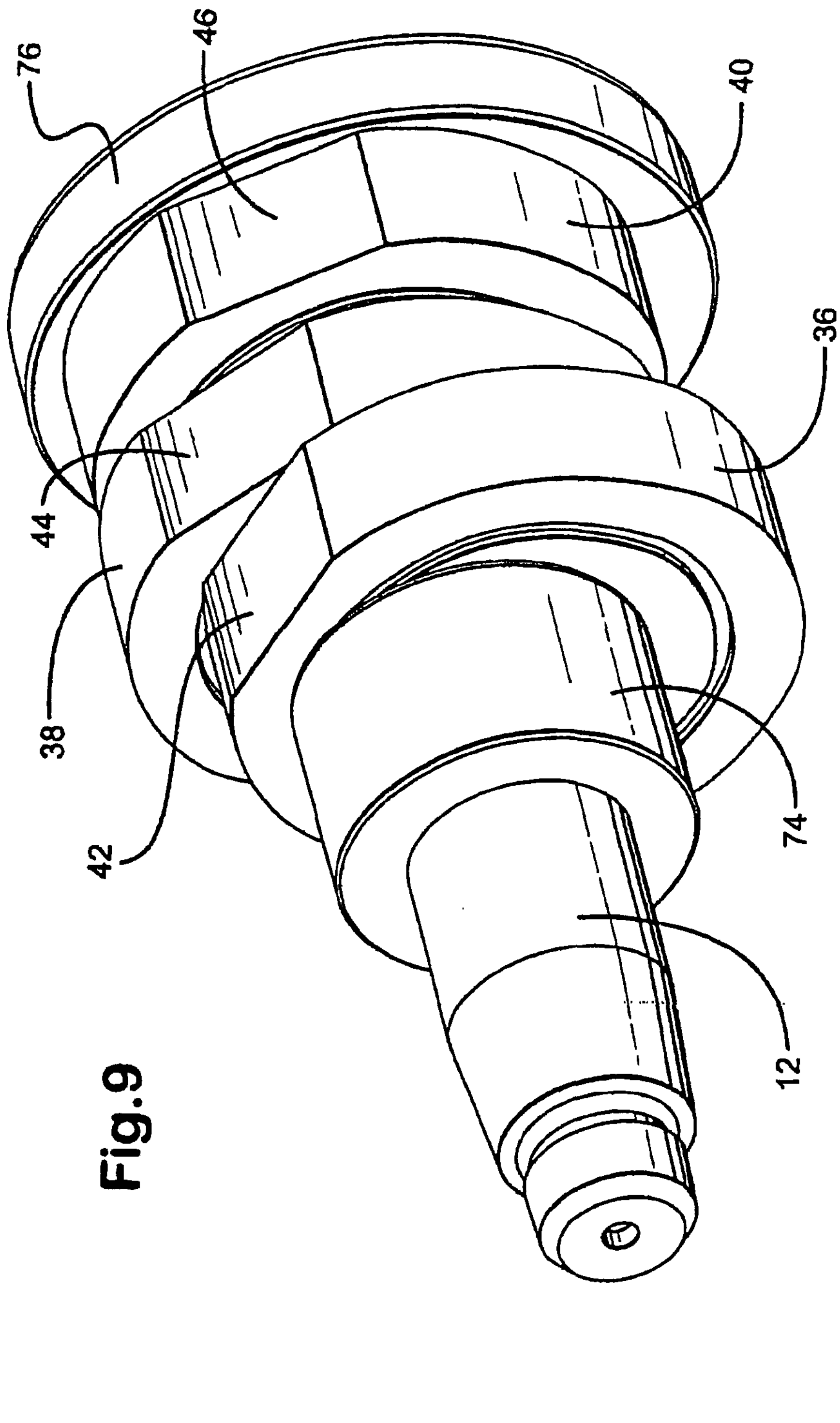


Fig.9

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 03 25 7949

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
A	US 4 687 426 A (YOSHIMURA HIROICHI) 18 August 1987 (1987-08-18) * column 2, line 34 - column 4, line 46 * ---	1	F04B1/053
A	EP 0 972 936 A (LUCAS IND PLC) 19 January 2000 (2000-01-19) * abstract * ---	1	
A	EP 1 184 568 A (DELPHI TECH INC) 6 March 2002 (2002-03-06) * abstract * ---	1-17	
A	EP 1 255 037 A (BOSCH AUTOMOTIVE SYSTEMS CORP) 6 November 2002 (2002-11-06) * column 1, line 44 - column 2, line 45 * -----	1	
			TECHNICAL FIELDS SEARCHED (Int.Cl.7)
			F04B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
MUNICH	26 March 2004	Fistas, N

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26-03-2004

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 4687426 A	18-08-1987	JP 61040467 A	26-02-1986
		JP 61049177 A	11-03-1986
		JP 61049181 A	11-03-1986
		CA 1254443 A1	23-05-1989
		EP 0172421 A2	26-02-1986
EP 0972936 A	19-01-2000	EP 0972936 A2	19-01-2000
		JP 2000038971 A	08-02-2000
		KR 2000016935 A	25-03-2000
EP 1184568 A	06-03-2002	GB 2366336 A	06-03-2002
		EP 1184568 A2	06-03-2002
EP 1255037 A	06-11-2002	JP 2001221118 A	17-08-2001
		EP 1255037 A1	06-11-2002
		WO 0159292 A1	16-08-2001
		US 2003010319 A1	16-01-2003

EPO FORM P0459

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