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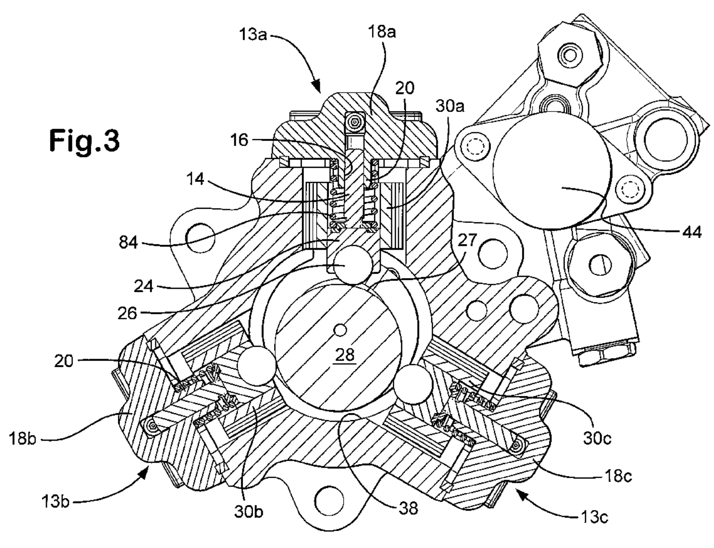
(54) **Fuel pump assembly**

(57) A fuel pump assembly for use in an engine, the fuel pump assembly comprising a plurality of pump heads (13a, 13b, 13c) mounted upon a main pump housing (10), wherein each of the pump heads (13a, 13b, 13c) includes a pumping plunger (14) which is reciprocable, in use, within a plunger bore (16) under the influence of an associated drive arrangement (24, 26) so as to cause pressurisation of fuel within a pumping chamber (22) defined within a pump head housing (18a). The drive arrangement of each pump head includes a shoe (24) and a roller (26) which is cooperable with a driven cam (28), common to each of the pump heads (13a, 13b, 13c), so as to impart reciprocal movement to the shoe (24) as the cam (28) is driven, in use. The shoe (24) is of substantially square or rectangular cross section an each pump head further includes an insert (30a) being formed as a separate part from the main pump housing (10) but being in permanent attachment therewith, wherein the insert (30a) defines a guide path of substantially rectangular or square cross section corresponding to that of the shoe (24) so that the guide path serves to guide movement of the shoe (24) upon reciprocal movement thereof.

Fig.3



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## Description

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

**[0002]** In a known fuel pump for use in a compression ignition internal combustion engine, a plurality of plungers are reciprocable within respective plunger bores so as to pressurise fuel within respective pumping chambers for delivery to the fuel injection system associated with the engine. It is common to provide three plungers which are equi-angularly spaced around a drive shaft, the plungers being moveable under the influence of a cam drive arrangement. The cam drive arrangement includes a common eccentric cam surface, which is cooperable with all three of the plungers to cause reciprocal movement of the plungers within their respective plunger bores in a phased, cyclical manner.

**[0003]** In an alternative known arrangement, each of the plungers is in connection with a cylindrical tappet member which serves to drive movement of the associated plunger within its bore. The tappets are slidable within tappet bores under the influence of respective roller members, driven by means of an eccentric cam surface. The eccentricity of the cam surface causes the tappets, and hence the plungers, to be driven inwardly within their respective bores, the plungers thereby performing a forward or pumping stroke in which fuel within the associated pumping chamber is pressurised. The tappets are urged outwardly from their associated tappet bores by means of fluid pressure within a working chamber, thus causing the respective plunger to be urged in an outward direction to perform the return stroke.

**[0004]** Pump arrangements of the aforementioned type can be difficult to assemble. Furthermore, the tappets require a relatively large accommodation space and are relatively expensive components. Parasitic pumping power losses are also an inherent feature of hydraulic tappet operation.

**[0005]** Our co-pending European patent application, EP 1223334A, describes a multi-plunger fuel pump in which three plungers are equi-angularly spaced around a drive shaft and driven under the influence of a reciprocable shoe and roller arrangement (a "roller-shoe" drive arrangement). The roller is cooperable with the cam surface of the cam arrangement so as to impart reciprocal movement to the shoe upon rotation of the drive shaft.

**[0006]** The pump includes three pump assemblies housed within a unitary, main pump housing, each of the pump assemblies including a plunger which is slidable within a respective bore in the housing to pressurise fuel within an associated pumping chamber.

**[0007]** Inlet and outlet valves to control fuel flow to and from the pumping chambers, respectively, are provided in flow passages defined within the main pump housing. A pump housing part in the form of a tubular member is arranged coaxially with the drive shaft and housed within the main pump housing. The tubular member is provided with a plurality of apertures, each of which is shaped to guide reciprocal movement of an associated shoe as the roller rides over the cam surface. The shoe associated with each plunger is of rectangular or square cross section.

**[0008]** One disadvantage of this type of pump is that it is difficult to manufacture main pump housings having shoe guide apertures which are other than cylindrical, and which have the desired degree of precision. Mismatching between the shoe and its guide path can lead to excessive wear of the shoe and/or the guide aperture.

**[0009]** It is an object of the present invention to provide an improved pump assembly for use in supplying high pressure fuel which alleviates at least one of the aforementioned problems.

**[0010]** According to a first aspect of the present invention, there is provided a fuel pump assembly for use in an engine, the fuel pump assembly comprising a plurality of pump heads mounted upon a main pump housing, each of the pump heads including a pumping plunger which is reciprocable, in use, within a plunger bore under the influence of an associated drive arrangement so as to cause pressurisation of fuel within a pumping chamber defined within a pump head housing, the drive arrangement including a shoe and a roller which is cooperable with a driven cam, common to each of the pump heads, so as to impart reciprocal movement to the shoe as the cam is driven, in use, the shoe being of square or rectangular cross section and each pump head further comprising an associated insert, being formed as a separate part from the main pump housing but being assembled permanently therewith, wherein the insert defines a guide path of substantially rectangular or square cross section for guiding reciprocating movement of the associated shoe.

**[0011]** The invention provides the advantage that the insert of each pump head which defines the shoe guide path can be more accurately formed as a separate component, prior to it being fixed permanently to the main pump housing. The problem encountered in known roller-shoe pump designs, that the accurate forming of a rectangular section guide path for the shoe is difficult to achieve, is therefore overcome by the present invention. As a result of being able to machine the shoe guide part with improved accuracy, wear on the guide path and the shoe is reduced.

**[0012]** Preferably, the insert of each pump head has an external surface profile of substantially cylindrical form.

**[0013]** As the shoes are components having a generally square or rectangular cross section, each of the inserts is preferably shaped to include two pairs of substantially parallel facing walls or internal surfaces (e.g. of substantially square or rectangular cross-sectional form).

**[0014]** Preferably, the insert associated with each pump head housing is formed by sintering or metal injection moulding (MIM).

**[0015]** Preferably, said main pump housing is provided with a plurality of openings in the form of radially extending bores in the main pump housing, each of the bores being adapted to receive one of the inserts having an outer surface of cylindrical form.

**[0016]** Preferably, the cylindrical insert of each pump head is an interference fit with the corresponding radially extending opening. Thus, although the insert is formed as a separate part from the main pump housing, when assembled within the housing it forms a permanent and immovable feature of the pump assembly. It is because the insert can be formed as a separate part, however, that their pairs of parallel facing walls can be formed conveniently, and with improved accuracy, compared with pump designs in which a main housing itself defines the guide path for the shoe.

**[0017]** Inward movement of a pumping plunger within its respective plunger bore causes the pumping plunger to perform a forward stroke, in which pressurisation of fuel within the pumping chamber occurs. Each pump head may be provided with a return spring which acts on the shoe so as to ensure the roller remains in engagement with the cam surface during a return stroke of the pumping plunger.

**[0018]** The roller may preferably take the form of a cylindrical roller.

**[0019]** In one preferred embodiment, the pump head housing has an integral plunger bore in the form of a plunger support tube extending substantially perpendicularly from the lower surface of the pump head housing so as to be located within the shoe guide path.

**[0020]** Preferably, a first end of the return spring, in the region of the pump head housing, surrounds the plunger support tube so as to retain the return spring in position.

**[0021]** Preferably, a second end of the return spring, distal to the pump head housing, is associated with positioning means to maintain the return spring in a fixed relationship with the shoe.

**[0022]** In one preferred embodiment the positioning means includes an annular groove on the radially outer surface of the shoe. In a further preferred embodiment the positioning means further includes a spring seat located on the inner end of the plunger, wherein the spring seat abuts the radially outer shoe surface.

**[0023]** In another preferred embodiment, the insert of each pump head is shaped to define, together with the opening in the main pump housing, a vent means for permitting fuel displaced by the shoe during reciprocating motion thereof to vent to low pressure. For example, the outer surface of each insert may be provided with at least one groove or recess which defines, together with the internal surface of the opening, a return flow path for fuel.

**[0024]** As the shoe reciprocates between the facing walls of its associated insert, the fuel volume radially inward of the shoe can escape relatively easily between the main bore, through drillings in the main pump housing and through the recesses or grooves formed in the external surface of the insert, which define the return flow path. The return flow path presents a relatively large flow area to fuel displaced by reciprocating motion of the shoes to ensure movement of the shoes is substantially unimpeded.

**[0025]** In one embodiment the fuel pump assembly has a pair of pump heads radially mounted upon the main pump housing at diametrically opposed positions about the drive shaft, and wherein the cam has a cam surface with a single cam lobe so as to impart phased, alternate motion to the respective plungers of the pair upon rotation of the shaft.

**[0026]** In the most preferred embodiment, the fuel pump assembly has three pump heads, and thus three associated inserts to define the shoe guide paths, the pump heads being radially mounted upon the may pump housing at equi-angularly spaced locations about a pump drive shaft.

**[0027]** According to a second aspect of the present invention there is provided fuel pump assembly for use in an engine, the fuel pump assembly comprising at least one pair of pump heads mounted upon a main pump housing, each of the pump heads including a pumping plunger which is reciprocable, in use, within a plunger bore under the influence of an associated drive arrangement so as to cause pressurisation of fuel within a pumping chamber defined within a pump head housing, each of the drive arrangements being co-operable with a surface of a cam which is driven, in use, by an associated engine drive shaft, so as to impart reciprocal movement to the pumping plunger upon rotation of the drive shaft, wherein the cam surface is common to each of the pump heads and wherein one pump head of the or each pair is positioned at substantially 90° to the other pump head of the pair, the cam surface being shaped to result in there being two pressurisation events for each pump head of said pair per cycle as the drive shaft rotates.

**[0028]** Preferably, only a single pair of pump heads are provided on the fuel pump assembly.

**[0029]** Preferably, the cam is a twin lobed cam. More preferably the cam lobes are diametrically opposed.

**[0030]** It will be apparent that in this preferred embodiment of the pump assembly according to the second aspect, four equally spaced pressurisation events will occur per cycle.

**[0031]** Preferably, each drive arrangement is a shoe and roller arrangement, or alternatively a slipper and tappet arrangement. It will be appreciated that, although it may be advantageous to provide the pump heads of the second aspect of the invention with an insert for guiding movement of the associated shoe, this is not essential.

**[0032]** The invention will now be described, by way of example only, with reference to the accompanying drawings in which:

Figure 1 is a perspective view of a fuel pump assembly in accordance with an embodiment of the present invention,

Figure 2 is a sectional view of the pump assembly in Figure 1,

Figure 3 is a sectional end view of the pump assembly in Figures 1 and 2,

Figure 4 is a perspective view of part of a main pump assembly housing,

Figure 5 is a sectional view of a part of a pump head of the pump assembly in Figures 1 to 4 to show inlet and outlet valves of the assembly, and

Figure 6 is a sectional view of the pump assembly of Figures 1 to 5 showing a high pressure fuel delivery passage.

**[0033]** Referring to Figures 1 to 3, there is shown a high pressure fuel pump assembly suitable for use in the fuel injection system of a compression ignition internal combustion engine. In particular, the fuel pump assembly is suitable for use in delivering high pressure fuel to the common rail of a common rail fuel injection system. The pump assembly includes a main pump housing 10 through which a cam drive shaft 12 of the engine extends along a drive shaft axis extending perpendicularly to the plane of the page. A front housing plate 11 is positioned on the main pump housing 10 and located by means of a boss 11 a. First, second and third pump heads 13a, 13b, 13c respectively are mounted upon the main pump housing 10 at approximately equi-angularly spaced radial locations around the drive shaft axis. The drive shaft 12 extends through a central through bore 40 provided in the main pump housing 10, and is supported by a plain bearing bush 41 and a front plate bearing 41a. Each pump head 13a, 13b, 13c includes a respective pump head housing 18a, 18b, 18c. On each pump head 13a, 13b, 13c a seal member 72 in the form of a gasket is located in a recess between the main pump housing 10 and the pump head housing 18a, 18b, 18c so as to form a fluid tight seal between these parts when the pump heads 13a, 13b, 13c are secured to the housing 10 by means if screws 92. The gasket seal 72 serves to seal low pressure regions of the pump from the high pressure regions of the pump, as discussed further below.

**[0034]** As the pump heads 13a, 13b, 13c are substantially identical to one another, only the first one of the pump heads 13a will be described in detail below. As can be seen most clearly in Figures 2 and 3, the first pump head 13a includes a pumping plunger 14 which is reciprocal within a blind bore 16 to perform a pumping cycle having a pumping stroke (or forward stroke) and a return stroke. The blind bore 16 is defined partly within a pump head housing 18a and partly within a plunger support tube 20 which extends from a lower surface of the pump head housing 18a. The bore 16 defines, at its blind end within the pump head housing 18a, a pumping chamber 22. Reciprocating movement of the plunger 14 within the bore 16 causes pressurisation of fuel within the pumping chamber 22 during the pumping stroke. The pumping plunger 14 is driven axially within the bore 16, in use, under the influence of a drive arrangement including a shoe 24 and an associated roller 26. The shoe is a component having a substantially rectangular cross section, although square section shoes may also be used. The roller 26 is co-operable with a cam surface 27 of a cam member 28 which is carried by the drive shaft 12. As the shaft 12 rotates in use, the roller 26 rides over the cam surface, imparting movement to the shoe 24 and, hence, imparting axial movement (i.e. along the main plunger axis) to the pumping plunger 14 within the bore 16 to drive the pumping stroke.

**[0035]** It will be appreciated that the shoe and roller arrangement of each pump head 13a, 13b, 13c co-operates with the cam surface 27, which is thus common to all three pump heads. As the drive shaft 12 rotates, the rollers co-operate with the common cam surface 27 to cause reciprocating motion of the shoes in a phased, cyclic manner depending on the cam surface profile.

**[0036]** Referring to Figure 4, a radially extending opening 32 in the form of a radially extending bore is provided in the main pump housing 10. The opening 32 defines an internal surface of substantially cylindrical form, and a first, hollow insert 30a, which is associated with the first pump head 13a, is located within the cylindrical opening 32 so as to be coaxial with the bore 16. The insert 30a has an outer surface of substantially cylindrical form, which corresponds to the shaping of the internal surface of the opening 32 in the main pump housing 10. The internal surface of the insert 30a defines a substantially rectangular cross section (in a plane perpendicular to the axis of movement of the plunger 14 and the shoe 24). The internal surface of the insert 30a therefore defines first and second pairs of substantially parallel facing walls 34, 36, which define a guide path of appropriate form for the rectangular section shoe 24 as it reciprocates, in use. The facing internal surfaces 34 of the first pair have a smaller length, along an axis perpendicular to the plunger axis, than the facing internal surfaces 36 of the second pair. The insert 30a is also formed so that the first pair of internal surfaces 34 have a longer length, along the direction of the plunger axis, than the second pair of internal surfaces 36, and thus upper end regions 130 of the insert 30a are of increased axial height.

**[0037]** It will be appreciated that although the cross section of the insert guide path is not exactly rectangular (e.g. due to interconnecting corner regions 230 being of curved form - as shown in Figure 4), a guide path of substantially rectangular cross section is defined to provide an adequate guiding surface for the generally rectangular cross section of the shoe 24.

**[0038]** The second and third pump heads 13b, 13c are also provided with similar inserts 30b, 30c, respectively, each of the inserts 30b, 30c being received within a correspondingly shaped radial opening or bore (such as 32) in the main pump housing 10. Each of first, second and third inserts 30a, 30b, 30c is arranged such that a radially inner end thereof opens into a main axial bore 38 provided in the main pump housing 10 (as can be seen in Figure 3).

**[0039]** The insert 30a also defines a spring space 74 located above the shoe 24 (in the orientation shown), within which a return spring 84 is located. The return spring 84 serves to urge the shoe 24 and the roller 26 in a radially inward direction such that the roller 26 maintains contact with the cam surface 27 throughout a complete rotation of the drive shaft 12. The force due to the return spring 84 is aided by the force due to fuel pressure within the pumping chamber 22 which acts on the pumping plunger 14 to provide a return force which serves to urge the pumping plunger 14 outwardly from the bore 16 to perform the return stroke. It will be appreciated that this only occurs if the pump is operating at its maximum displacement and, hence, at maximum filling.

**[0040]** The outer surface of the insert 30a is provided with first and second recesses 82a, 82b. The recesses 82a, 82b are provided along those facing sides of the insert 30a which define the longer of the facing internal wall surfaces 36. The recesses 82a, 82b are thus formed in the region of the insert 30a which would otherwise be formed from the greatest amount of insert material. A plurality of drillings 80 are provided in the main pump housing 10 which, together with the recesses 82a, 82b provided in the outer surface of the insert 30a, define a vent passage means in the form of a return flow path, as discussed further below.

**[0041]** As can be seen most clearly in Figure 5, the return spring 84 is of a diameter such that a first end is located around, and retained in position by, the plunger support tube 20. The second end of the return spring 84 abuts a spring seat 86 attached to the pumping plunger 14 by a retention clip 88. The clip 88 acts to maintain the spring seat 86 in position. The spring seat 86 is located in and spaced from an annular groove 90 provided on the radially outer surface of the shoe 24.

**[0042]** A low pressure transfer pump 42 is mounted upon the housing 10 at an end face remote from the front plate 11. The transfer pump 42 is arranged to supply fuel at a pressure dependent upon the speed of rotation of the engine, the rate of flow of fuel from the transfer pump being controlled by means of a metering valve arrangement 44 in a conventional manner The transfer pump 42 also supplies fuel at a low pressure to the main bore 38 and the spring space 74 through a drilling 76 in the main housing 10.A back leak connector 45 is mounrted upon the front plate 11 in a conventional manner for use in the return of fuel from the pump assembly to a low pressure fuel reservoir (not shown).

**[0043]** Referring also to Figure 5, it can be seen that the gasket seal 72 is a generally square frame seal having a side-tab seal portion 72b. The metered flow of fuel from the transfer pump 42 is supplied to an entry drilling 55 provided in the pump head housing 18a, which extends through an aperture 72a in the side tab portion 72b of the gasket seal 72. The entry drilling 55 communicates with the pump chamber 22 through an inlet valve arrangement 46, and thus defines a flow path for relatively low pressure fuel into the pumping chamber 22. The upper end region 130 of the insert 30a defines a support or abutment for the gasket seal 72, which aids unwanted movement of the seal 72 relative to the housing surface 10, and thus benefits the gasket sealing function.

**[0044]** The inlet valve arrangement 46 includes a disc-like valve member 58 which is operable in response to fuel pressure within a further drilling 64 so as to control the flow of fuel into the pumping chamber 22 from the drillings 55, 64. The further drilling 64 is defined within an inlet valve body 59 and communicates with an outlet end of the entry drilling 55. The inlet valve body 59 is sealed within a bore in the pump head housing 18a by means of an O-ring 57 and a deformable knife-edge seal 60. The valve member 58 is biased closed by means of a first valve spring 56 and, if fuel pressure within the further drilling 64 exceeds a predetermined amount, the valve member 58 is caused to lift away from its seating, against the force of the spring 56, to permit a metered flow of fuel (at "metered fuel pressure") to be suppplied through the further drilling 64 to the pumping chamber 22.

**[0045]** The pumping chamber 22 is also provided with an outlet valve arrangement 48 which is arranged to open when fuel pressure within the pumping chamber 22 is pressurised to a level greater than a predetermined amount. The outlet valve arrangement 48 takes the form of a ball valve including a ball 66 which is urged against a valve seating 67 by means of fuel pressure in the high pressure drillings. The ball valve controls communication between the pumping chamber 22 and a common delivery passage 50. A high pressure sealing member 70 is located between the outlet valve 48 and the common delivery passage 50. Conveniently, the sealing member 70 may be a metal sealing washer of double knife-edged form which is trapped in an annular recess in the main pump housing 10. If the ball valve is urged open, fuel is able to flow from the pumping chamber 22, past the second valve seat 67 and into the first arm 50a of the common delivery passage 50. The high pressure sealing member 70 has first and second so called 'knife-edge" sealing faces to ensure substantially no high pressure fuel leaks from the common delivery passage 50.

**[0046]** As shown in further detail in Figure 6, the common delivery passage 50 is defined within the main housing 10 and is common to all three of the pump heads 13a, 13b, 13c. The common delivery passage 50 includes first, second and third radially extending arms 50a, 50b, 50c which define a flow passage of generally 'Y' shaped configuration such that stress concentration between the arms is minimised. Fuel is delivered through the first one of the arms 50a to a common outlet port 52, through which high pressure fuel is delivered to the downstream parts of the fuel injection system, for example a common rail. The high pressure delivery passage 50 also communicates with a high pressure limiting valve assembly 54 which acts to control the fuel pressure level within the housing 10.

**[0047]** In use, metered fuel is delivered from the transfer pump 42 to the further drilling 64. If inlet fuel pressure exceeds an amount which is sufficient to overcome the force due to the first valve spring 56 and any pressure in the pumping chamber 22, the valve member 58 will be urged away from its seating to permit fuel flow into the pumping chamber 22. As the drive shaft 12 rotates, the rollers 26 of each of the pump heads 13a, 13b, 13c are caused to move in a radially outward direction, thereby imparting movement to the associated shoe 24, such movement of the shoe 24 being guided by co-operation between the shoe and the walls 34, 36 of the insert 30a. The pumping plunger 14 is caused to move axially within its bore 16 to pressurise fuel within the pumping chamber 22. When fuel pressure within the pumping chamber 22 exceeds an amount which is sufficient to overcome the force acting on the ball 66 due to any pressure within the common rail connected to the common outlet port 52, the outlet valve arrangement 48 is caused to open to permit high pressure fuel to flow from the pumping chamber 22, through the passage into the delivery passage 50.

**[0048]** Fuel is also supplied by the transfer pump 42 to the pumping chambers of the second and third pump heads 13b, 13c such that, as the drive shaft 12 rotates and the respective rollers ride over the cam surface, the shoes reciprocate cyclically within their respective bores to pressurise fuel within the pumping chambers of the second and third pump heads 13b, 13c also.

**[0049]** The main pump housing 10 is filled with fuel at relatively low pressure (commonly referred to as "housing pressure" and generally controlled by a housing pressurising valve or an exit orifice) through a restricted feed (not shown) from the transfer pump 42. Fuel pressure within this volume applies a force to the shoe 24, and hence to the associated pumping plunger 14, which serves to oppose outward movement of the pumping plunger 14 from the plunger bore 16. As the shoe 24 reciprocates between the facing walls 34, 36 of the insert 30a, it is important that fuel within the volume radially inward of the shoe 24 can escape relatively easily as, if this volume is not vented, fuel pressure within the volume will tend to increase upon radially inward movement of the shoe 24. Fuel passes between the main bore 38 and the spring space 74 through the drillings 80 in the main pump housing, and through the recesses 82a, 82b formed in the external surface of the insert 30a. The drillings 80 and the recesses 82a, 82b define a return flow path for fuel displaced by the shoe 24 between the spring space 74 and the main axial bore 38, from where fuel flows to the low pressure return 45. The return flow path presents a relatively large flow area to fuel displaced by reciprocating motion of the shoes to ensure movement of the shoes 24 is substantially unimpeded, and thus fuel pressure in the space 74 remains similar to that in the main bore 38.

**[0050]** It is a further benefit of the recesses 82a, 82b on the outer surface of the insert 30a that a more uniform contact pressure can be achieved between the outer diameter of the cylindrical insert 30a and the opening 32 in the main pump housing 10.

**[0051]** In an alternative embodiment (not shown), the spring seat 86 for the return spring 84 and the retention clip 88 are removed, such that the return spring 84 acts directly on the shoe 24. In this embodiment, pressure in the space 74 acts on the exposed end of the plunger 14, and thus opposes to some extent (but does not prevent altogether) the entry of fuel into the pumping chamber 22. The plunger 14 is maintained in contact with fuel entering the chamber 22 during the filling stroke, and the formation of vends or air bubbles in the filling circuit is prevented. In this case, a reduced pressure difference is necessary to open the valve 58.

**[0052]** One advantage of the present invention is that the use of a separate insert 30a to define a shoe guide path having a rectangular or square cross section to correspond with that of the shoe can be produced more accurately and easily. Wear and manufacturing difficulties are therefore reduced compared to existing roller-shoe pump designs. A further advantage of the present invention is that the shoe and roller arrangements 24, 26 may be assembled within each individual insert in the main pump housing 10 before the pump head housings 18a,18b, 18c are mounted upon the main pump housing 10. Thus, manufacturing difficulties in assembling the shoe and roller arrangement 24, 26 from inside the main pump housing 10 are avoided. As the pump assembly is of multi-part construction, access for machining precision is also greatly improved and the assembly is readily adaptable for different user requirements.

**[0053]** In order to assemble the pump assembly, initially each of the pump heads 13a, 13b, 13c is assembled separately to include the respective pumping plunger 14, the inlet and outlet valve arrangements 46, 48, and the spring 84. The insert 30a is introduced into the passage 32 in the main pump housing 10 and is secured thereto in such a manner that it forms an interference fit with the opening 32 in the main pump housing 10 to become a permanent feature of the housing 10 (i. e. assembled in a permanent manner within the housing 10). By way of example, the insert 30a may be formed conveniently by sintering or by means of metal injection moulding (MIM).

**[0054]** The shoe 24 and the roller 26 are then positioned in the insert Each assembled pump head 13a, 13b, 13c may then be presented to the main pump housing 10, such that the pumping plunger 14 and the return spring 84 are positioned against the shoe and roller arrangement 24, 26 of each pump head with the spring seat 86 received in the annular groove 90.

**[0055]** For each pump head, the pump head housing 18a,18b, 18c is clamped against the main pump housing 10, to compress the return spring 84 and the seals 70, 72 between the pump head housing 18a, 18b, 18c and the main pump housing 10. The screws 92 (as shown in Figure 1) are tightened into the screw-threaded drillings in the main pump housing 10 to secure the pump head housings 18a, 18b, 18c directly to the main pump housing 10.

**[0056]** In an alternative embodiment of the invention (not shown) a pair of pump heads, as described previously, is mounted upon a main pump housing, with one pump head of each pair being mounted upon the drive shaft at substantially 90° to the other pump head of the pair. The cam arrangement takes the form of a twin-lobed cam having two cam surfaces, shaped to result in there being two pressurisation events for each pump head of said pair per cycle as the drive shaft rotates. Such an arrangement provides particular advantage in smaller engines, where accommodation space is limited. It will be appreciated that for this embodiment of the invention, the drive arrangement for the pump head pair may be a roller/shoe or a slipper/tappet and need not be mounted in inserts 30a, 30b but may be guided within a guide path defined by the respective pump head housing 18a, 18b. Further pairs of pump heads may also be provided to enable a higher number of pressurisation events per cycle, if required. In a further embodiment (not shown) a pair of pump heads is mounted on the main housing diametrically opposite one another, such that rotation of the drive shaft and the associated cam results in the plungers pumping in an alternate, phased manner. In other words when a plunger of one of the pump heads is at the top of its stroke, the plunger of the other pump head is at substantially the bottom of its stroke. It is envisaged that such an embodiment would be suitable for use in applications requiring a reduced rate of fuel delivery to the common rail.

## Claims

1. A fuel pump assembly for use in an engine, the fuel pump assembly comprising a plurality of pump heads (13a, 13b, 13c) mounted upon a main pump housing (10), wherein each of the pump heads (13a, 13b, 13c) includes:

    a pumping plunger (14) which is reciprocable, in use, within a plunger bore (16) under the influence of an associated drive arrangement (24, 26) so as to cause pressurisation of fuel within a pumping chamber (22) defined within a pump head housing (18a),

    the drive arrangement including a shoe (24) and a roller (26) which is cooperable with a driven cam (28), common to each of the pump heads (13a, 13b, 13c), so as to impart reciprocal movement to the shoe (24) as the cam (28) is driven, in use,

    the shoe (24) being of substantially square or rectangular cross section, and

    each pump head (13a, 13b, 13c) having an associated insert (30a) being formed as a separate part from the main pump housing (10), but being assembled permanently therewith, wherein the insert (30a) defines a guide path of substantially rectangular or square cross section corresponding to that of the shoe (24), so that the guide path serves to guide reciprocating movement of the shoe (24).

2. A fuel pump assembly as claimed in claim 1, wherein the insert (30a, 30b, 30c) associated with each pump head (13a, 13b, 13c) is formed by sintering.

3. A fuel pump assembly as claimed in claim 1, wherein the insert (30a, 30b, 30c) associated with each pump head (13a, 13b, 13c) is formed by metal injection moulding.

4. A fuel pump assembly as claimed in any one of the preceding claims, wherein the insert (30a, 30b, 30c) associated with each pump head (13a, 13b, 13c) has an outer surface of substantially cylindrical form.

5. A fuel pump assembly as claimed in any one of the preceding claims, wherein the insert (30a, 30b, 30c) has an internal surface defining two pairs of substantially parallel facing walls (34, 36).

6. A fuel pump assembly as claimed in any one of the preceding claims, wherein the main pump housing (10) has a plurality of openings (32), each opening (32) defining an internal surface of substantially cylindrical form, wherein each of the inserts (30a, 30b, 30c) is received permanently within a respective one of the openings (32) to guide reciprocating movement of an associated shoe (24).

7. A fuel pump assembly as claimed in claim 6, wherein the openings (32) take the form of radially extending bores provided in the main pump housing (10).

**8.** A fuel pump assembly as claimed in claim 7, wherein the insert (30a, 30b, 30c) forms an interference fit with the opening (32).

**9.** A fuel pump assembly as claimed in any of claims 6 to 8, wherein the insert (30a, 30b, 30c) defines, together with the associated opening (32) in the main pump housing (10), a vent means for permitting fuel displaced by the shoe (24) during reciprocating motion thereof to vent to low pressure.

**10.** A fuel pump assembly as claimed in claim 9, wherein the outer surface of the insert (30a, 30b, 30c) is provided with at least one groove or recess (82a, 82b) which defines, together with the internal surface of the associated opening (32), a return flow path for fuel to low pressure.

**11.** A fuel pump assembly as claimed in any one of the preceding claims, wherein the cam (28) defines a cam surface (27) over which the roller (26) rides, in use, wherein each pump head (13a, 13b, 13b) is provided with a return spring (84) which acts on the shoe (24) so as to ensure the roller (26) remains in engagement with the cam surface (27).

**12.** A fuel pump assembly as claimed in claim 11, wherein a first end of the return spring (84), in a region of the pump head housing (18a), surrounds the plunger support tube (20) so as to retain the return spring (84) in position.

**13.** A fuel pump assembly as claimed in claim 11 or claim 12, wherein a second end of the return spring (84), distal to the pump head housing (18a), is associated with positioning means (86, 88, 90), which serves to maintain the return spring (84) in a fixed relationship with the shoe (24).

**14.** A fuel pump assembly as claimed in claim 13, wherein the positioning means includes an annular groove (90) on the radially outer surface of the shoe (24).

**15.** A fuel pump assembly as claimed in claim 14, wherein the positioning means includes a spring seat (86) located on or otherwise attached to an end of the plunger (14), and wherein the spring seat (86) locates within the annular groove (90).

**16.** A fuel pump assembly as claimed in any one of the preceding claims, wherein the roller is a cylindrical roller (26).

**17.** A fuel pump assembly as claimed in any one of the preceding claims, wherein the pump head housing (18a) has an integral plunger bore (16) defined in a plunger support tube (20), the plunger support tube (20) extending substantially perpendicularly from a lower surface of the pump head housing (18a) so as to be located at least partially within the shoe guide path.

**18.** A fuel pump assembly as claimed in any one of the preceding claims, including a pair of pump heads (13a, 13b) radially mounted upon the main pump housing (10) at diametrically opposed positions about a pump drive shaft (12) carrying the cam (28), the cam (28) having a cam surface (27) with a single cam lobe so as to impart phased, alternate motion to respective plungers (14) of the pair of pump heads (13a, 13b) upon rotation of the shaft (12).

**19.** A fuel pump assembly as claimed in any one of claims 1 to 17, including (10) at equi-angularly spaced locations about a pump drive shaft (12) carrying the cam (28).

**20.** A fuel pump assembly for use in an engine, the fuel pump assembly comprising;
at least one pair of pump heads (13a, 13b) mounted upon a main pump housing (10), each of the pump heads including a pumping plunger (14) which is reciprocable, in use, within a plunger bore (16) under the influence of an associated drive arrangement (24, 26) so as to cause pressurisation of fuel within a pumping chamber (22) defined within a pump head housing (18a, 18b), each of the drive arrangements being co-operable with a surface (27) of a cam (28) which is driven, in use, by an associated engine drive shaft (12), so as to impart reciprocal movement to the pumping plunger (14) upon rotation of the drive shaft,
wherein the cam (28) is common to each of the pump heads (13a, 13b) and wherein one pump head of the or each pair is positioned at substantially 90° to the other pump head of the pair, the cam (28) being shaped to result in there being two pressurisation events for each pump head (13a, 13b) of said pair per pumping cycle as the drive shaft rotates.

**21.** A fuel pump assembly as claimed in claim 20, including only a single pair of pump heads.

**22.** A fuel pump assembly as claimed in claim 20 or claim 21, wherein the cam is a twin-lobed cam, thereby to provide four equally spaced plunger pumping strokes per pumping cycle.

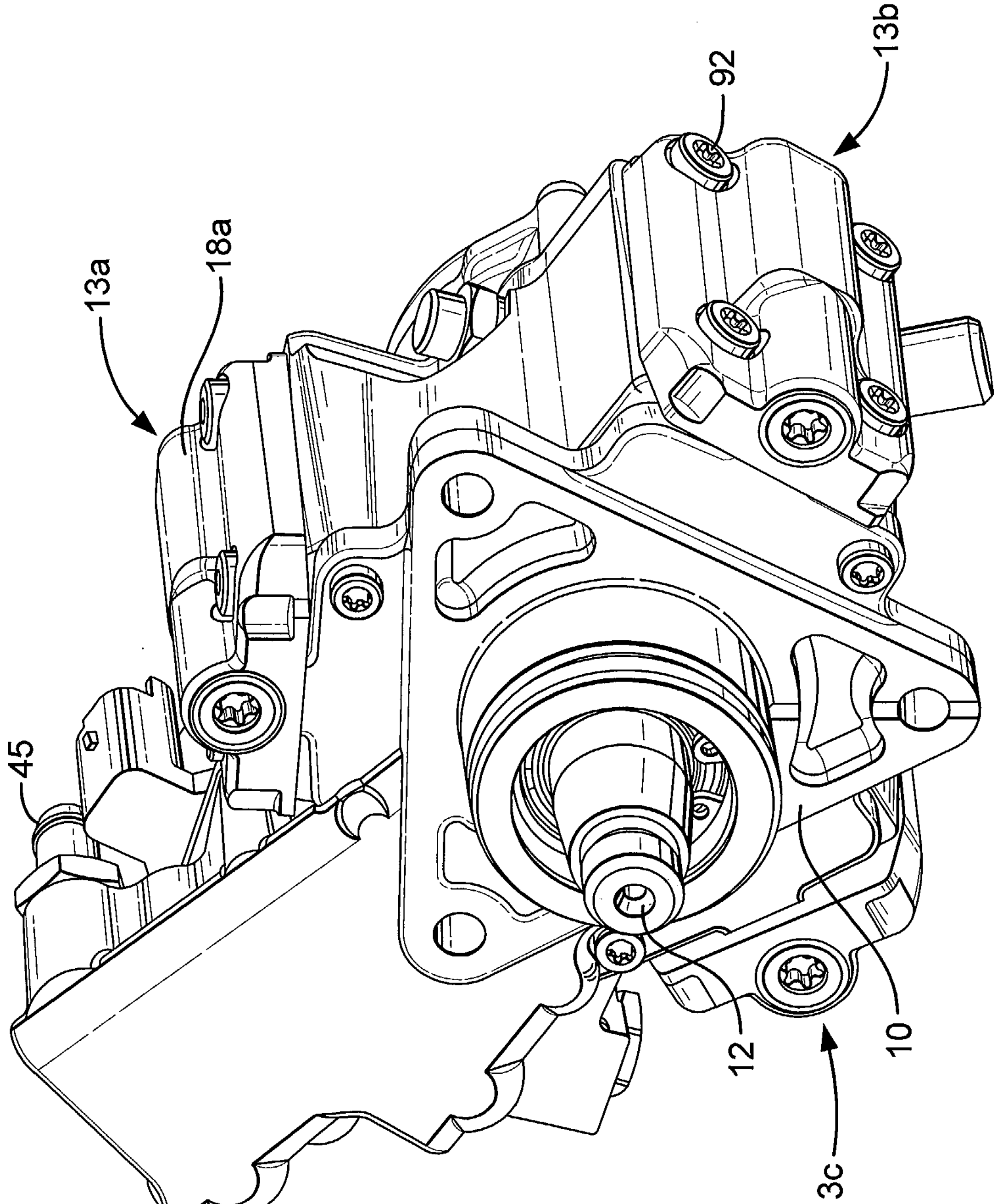
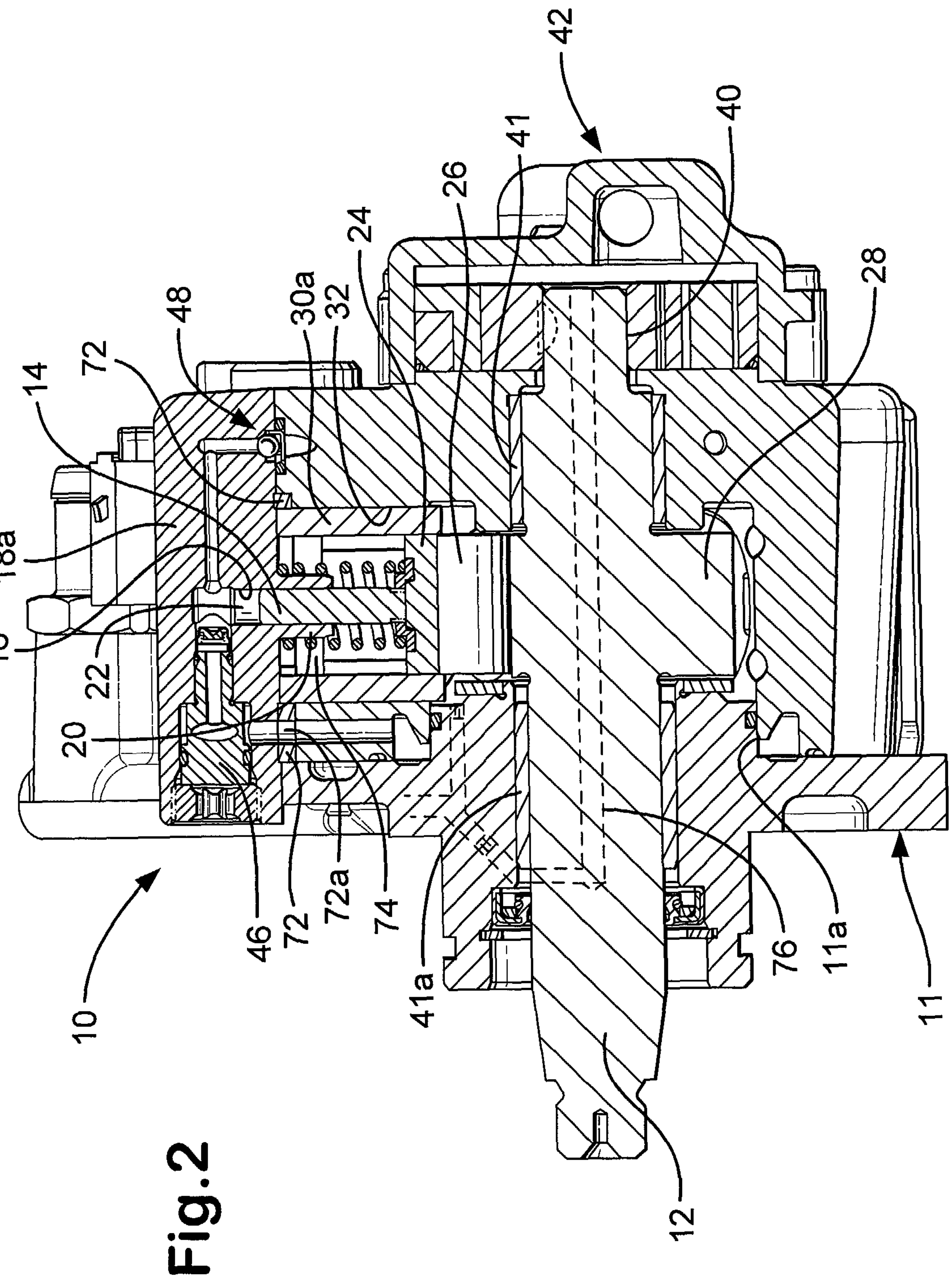



Fig.1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12

Fig.2

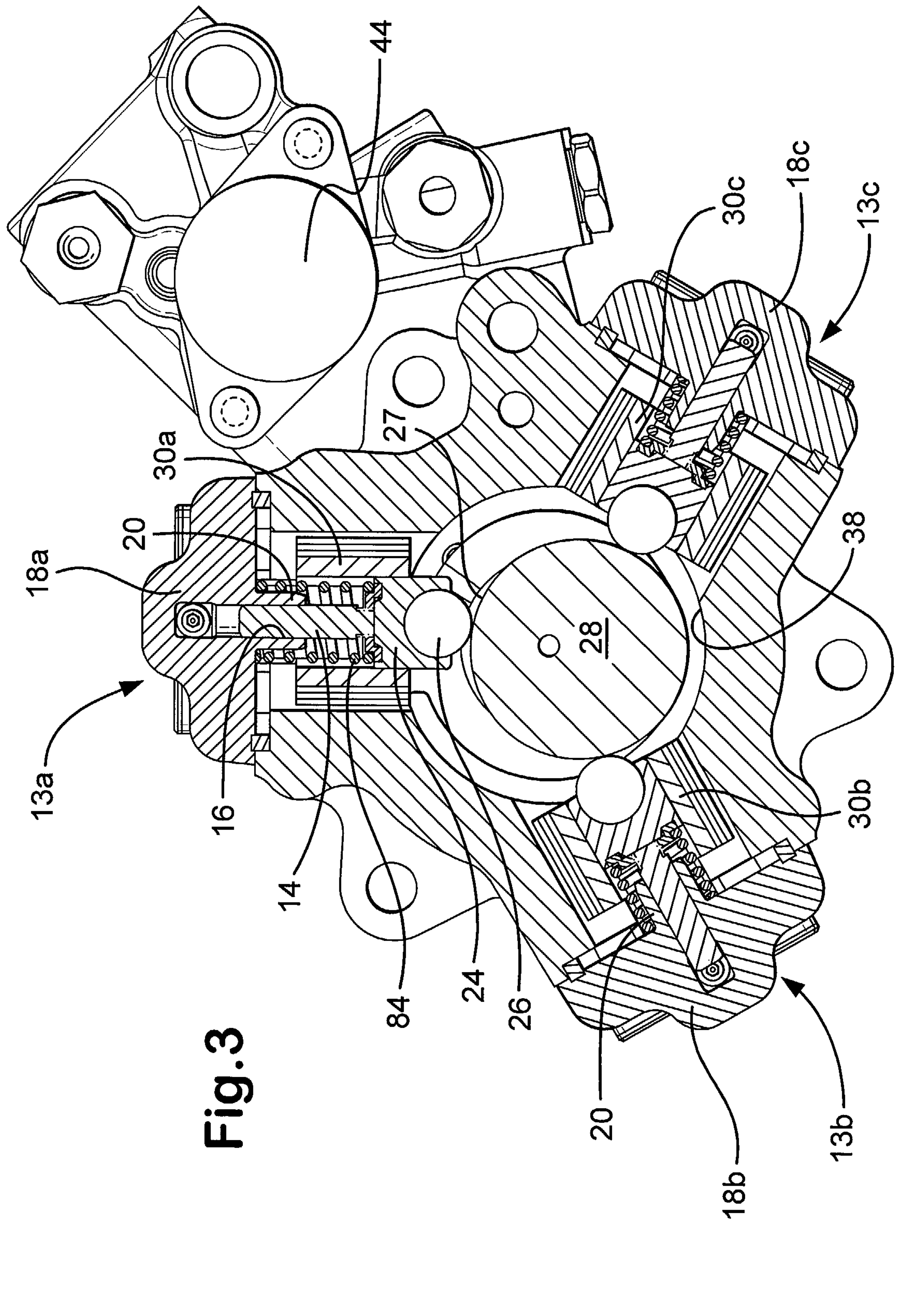
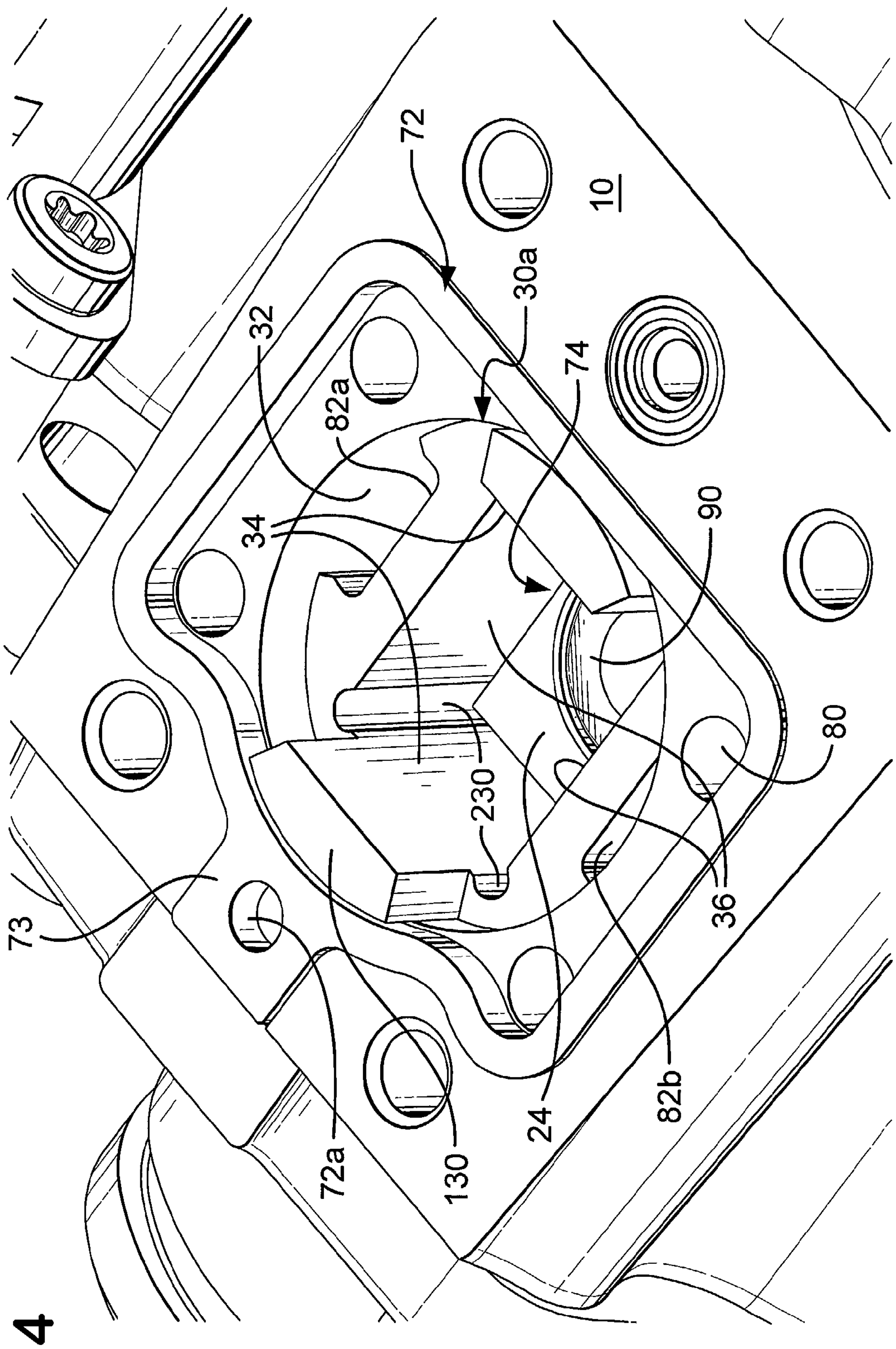
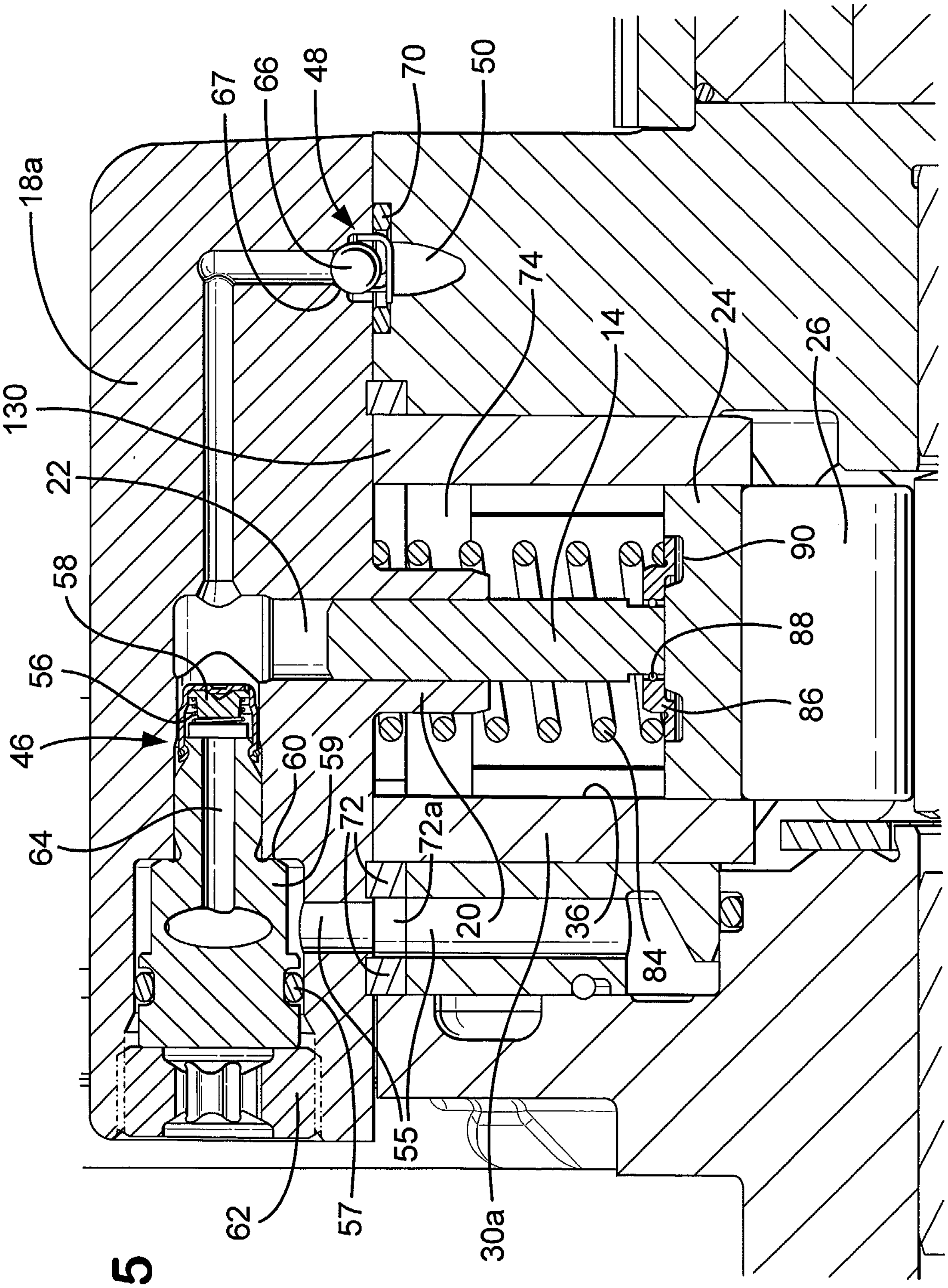



Fig.3

Fig.4

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22
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90
88
86
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57
62
30a

Fig.5

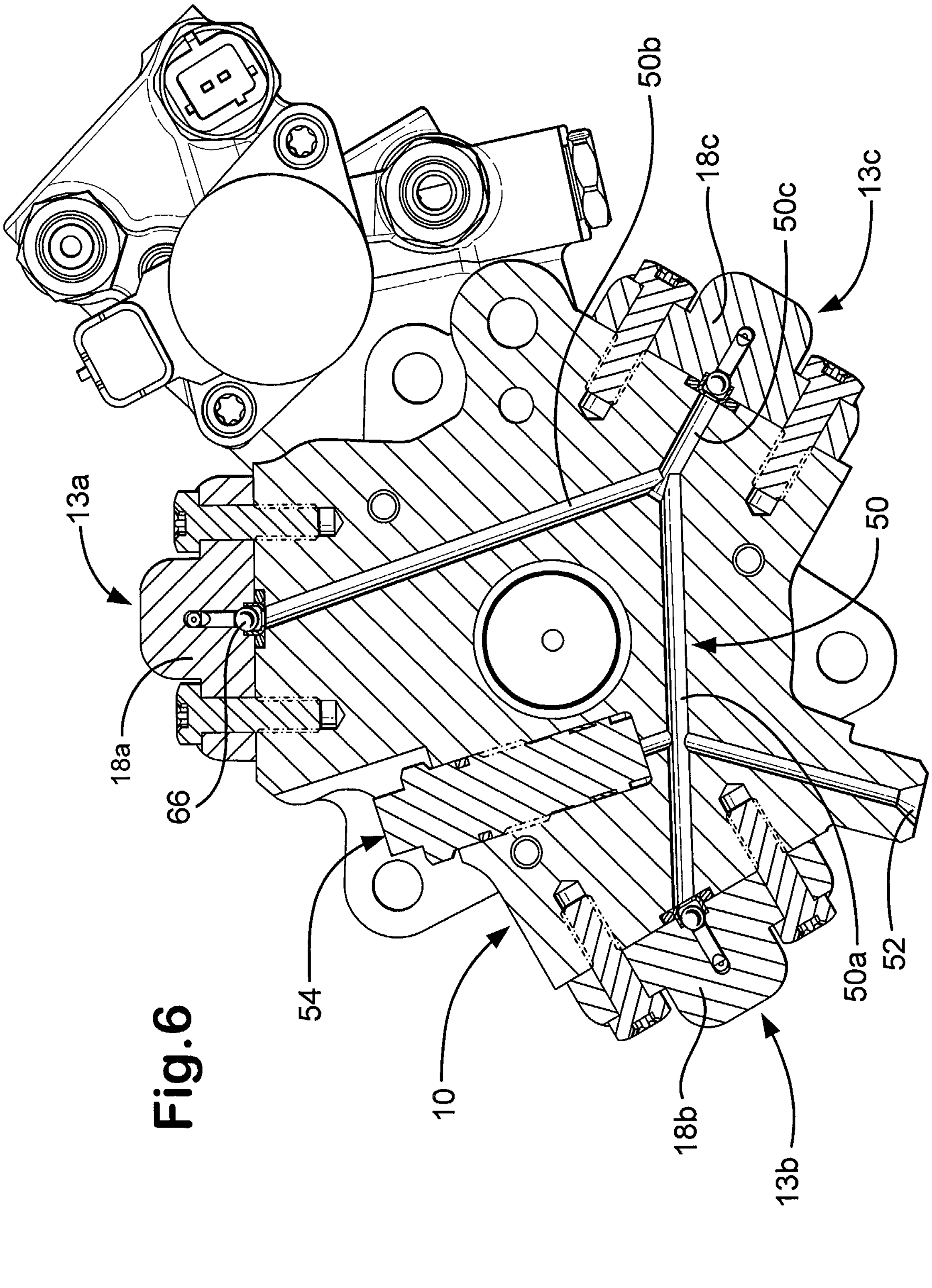


Fig.6