(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 0 972 936 A2**

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
19.01.2000 Bulletin 2000/03

(51) Int Cl.[7]: **F04B 1/04**

(21) Application number: **99305492.3**

(22) Date of filing: **12.07.1999**

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE
Designated Extension States:
AL LT LV MK RO SI

(30) Priority: **14.07.1998 GB 9815272**

(71) Applicant: **LUCAS INDUSTRIES public limited company**
London W1Y 4DJ (GB)

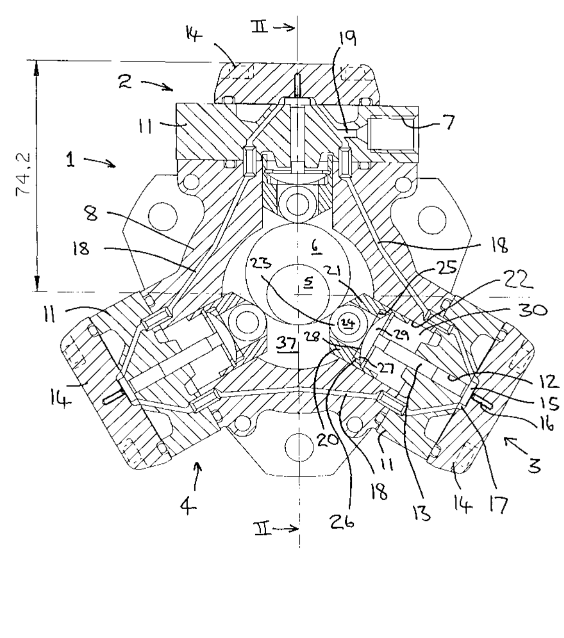
(72) Inventors:
- **Parker, Stephen Michael**
  Redhill, Surrey RH1 5TW (GB)
- **Cooke, Michael Peter**
  Gillingham, Kent ME7 1DR (GB)
- **Thornthwaite, Ian Roy**
  Gillingham, Kent ME7 3PJ (GB)
- **Collingborn, Peter Alban**
  Gillingham, Kent ME8 8RX (GB)

(74) Representative: **Goodenough, Nigel et al**
A.A. Thornton & Co.
235 High Holborn
London WC1V 7LE (GB)

(54) Positive displacement pumps

(57) A high pressure positive displacement pump, for example suitable for delivering fuel to a fuel injection system comprises one or more pumping assemblies (2,3,4). Each pumping assembly comprises a cylinder block (11) which defines a pumping cylinder (12) in which a pumping plunger (13) is slidably mounted. Each pumping plunger is connected to a tappet assembly (20) which comprises a tappet shell (21) slidably mounted in a bore (22). In use, the tappet assemblies engage a cam (6) to drive the pumping plungers in the pumping direction. A working fluid chamber (30) is defined on the side of each tappet assembly (20) opposite to the cam (6). In use, pressurised working fluid is delivered to the working fluid chamber (30) to drive the tappet and pumping plunger in the return direction. The arrangement obviates the need to provide a return spring for the pumping plungers.

Fig 1



EP 0 972 936 A2

Description

[0001] This invention relates to a positive displacement pump and, in the preferred embodiment, provides a pump suitable for delivering high pressure fuel to the fuel injection system of an internal combustion engine. It is to be understood, however, that the invention is not limited to pumps of this particular type and is generally applicable to a wide range of positive displacement pumps.

[0002] In a positive displacement pump a pumping plunger reciprocates within a cylinder to vary the volume of a pumping chamber and effect, with the aid of suitable valving, delivery of the pumped fluid. During the delivery stroke of the plunger a force is applied to the plunger in order to drive fluid from the pumping chamber. Each delivery stroke is followed by a return stroke in which the plunger moves in the opposite direction to increase the volume of the pumping chamber.

[0003] In pumps of a large size it is conventional to use a crankshaft or cam arrangement for driving the pump plunger, and the pump plunger is connected to the crank shaft or cam so that it is driven during both the forward pumping stroke and the return fill stroke. In pumps of a small size, however, the provision of a mechanical link between the pump plunger and the driving crank or cam is not possible and under these circumstances it is common to use a spring for the purpose of driving the pump plunger during the return (fill) stroke. There are certain circumstances, however, where the use of a spring is undesirable.

[0004] The present invention provides a novel means of driving the pump plunger of a positive displacement pump in the return direction.

[0005] According to one aspect of the present invention a positive displacement pump comprising a cylinder, a pump plunger slidably mounted in the cylinder to define therewith a pumping chamber, and drive means for driving the pump plunger in a forward direction to reduce the volume of the pumping chamber to effect delivery of a pumped fluid is characterised in that: a piston is coupled to the pump plunger; the piston is slidably mounted in a bore defined in the pump so as to define a working chamber the volume of which increases as the volume of the pumping chamber increases; and means are provided for supplying working fluid under pressure to the working chamber to generate a force on the piston in the return direction tending to increase the volume of the pumping chamber.

[0006] Working fluid under pressure may be supplied to the working chamber only during return strokes of the piston. However, in a preferred arrangement working fluid under pressure is present in the working chamber at all times and the drive means is effective to move the pump plunger against the force generated by the working fluid during forward strokes of the pump plunger.

[0007] Preferably the working fluid is a hydraulic fluid and in a particularly preferred embodiment of the invention the working fluid is lubricating oil. If the pump is to be used in association with an internal combustion engine, for example to deliver fuel to the internal combustion engine, the lubricating oil can advantageously be derived from the lubrication system of the internal combustion engine.

[0008] In a particularly preferred embodiment of the invention the piston is formed by a tappet assembly which, as well as performing its function as a piston, acts to transmit force from a drive cam to the pump plunger during forward strokes of the pump plunger.

[0009] If, as in the preferred embodiment of the invention, the piston is a tappet assembly the presence of pressurised lubricating oil in the working chamber will lubricate the tappet assembly as well as providing the required return force. Under these circumstances, it is preferable to allow some oil to escape from the working chamber past the tappet assembly into the cam chamber of the pump so as to lubricate the cam and, optionally, the drive shaft bearings of the pump.

[0010] In a particularly preferred embodiment of the invention where a plurality of pump plungers is provided the working chambers associated with the respective pump plungers are preferably interconnected to allow working fluid to flow between the working chambers as the respective pump plungers reciprocate. An accumulator may be provided to maintain working fluid pressure and to receive surplus working fluid as the total volume of the working chambers varies during rotation of the drive shaft of the pump.

[0011] In a particularly preferred embodiment of the invention each pump plunger is formed with a head which is secured to and forms part of the tappet assembly. The head can conveniently be used to close the interior space of the tappet assembly and thereby allow the tappet assembly to act as a piston. Preferably, the tappet comprises a tappet shell within which the head is received and a slipper is interposed between the head of the plunger and the tappet shell. Preferably, the slipper includes a flat face which engages a complementary flat face of the tappet shell and a part-spherical or part-conical face which engages a complementary part-spherical face of the pump plunger head. Such an arrangement accommodates misalignment of the pump cylinder and the tappet bore.

[0012] Whilst the invention is particular applicable to a fuel pump suitable for delivering high pressure fuel to the fuel injection system of an internal combustion engine, it should be appreciated that the invention is not limited to such applications. Further, the invention is generally applicable to a wide range of plunger configurations and can be applied successfully to constructions in which the plungers are arranged in axial (parallel) orientation, or in a fan or a conical arrangement. Further, the invention is applicable to a wide range of drive mechanisms, for example external or internal cams or swash plate drives. It is further to be appreciated that whilst lubricating oil, and in particular engine oil, is the preferred working fluid in the preferred embodiment of the invention, other arrangements are possible.

[0013] The invention will be better understood from the following description of a preferred embodiment thereof, given by way of example only, reference being had to the accompanying drawings wherein:

Figure 1 is a transverse cross-sectional view, generally on the line I-I of Figure 2, of a high pressure fuel pump;
Figure 2 is a longitudinal section of the pump of Figure 1, taken generally along the line II-II of Figure 1;
Figure 3 is a transverse section generally along the line III-III of Figure 2;
Figure 4 is a schematic cross-sectional view on the line IV-IV of Figure 5 showing a second embodiment of the invention;
Figure 5 is a schematic longitudinal section of the pump of Figure 4, taken generally along the line V-V of Figure 4; and
Figure 6 shows the phasing arrangement of the pump of Figures 4 and 5.

[0014] The high pressure fuel pump shown in Figure 1-3 is suitable for use in the fuel injection system of an internal combustion engine, and in particular is suitable for delivering high pressure fuel to an accumulator or the common rail of a common rail fuel injection system.

[0015] The illustrated pump 1 comprises three pumping assemblies 2,3 and 4 located in a common radial zone and spaced 120° apart around a drive shaft 5. The shaft 5 carries a single cam 6 for driving the pumping assemblies to deliver high pressure fuel from an outlet 7.

[0016] The drive shaft 5 is supported in a pump body 8 by a front bearing 9 and a rear bearing 10. In use, the pump body 8 is secured to an internal combustion engine and an appropriate rotary drive from the engine is used to rotate the shaft 5.

[0017] The pumping assemblies 2,3,4 are substantially identical to each other and, in the interests of brevity, only the pumping assembly 3 will be described in detail.

[0018] The pumping assembly 3 comprises a cylinder block 11 which defines a pumping cylinder 12. A pumping plunger 13 is slidably mounted in the cylinder 12 and, in use, is reciprocated along the cylinder 12 to vary the volume of a pumping chamber defined by the plunger, the cylinder and a cylinder head 14 in a cyclic manner. The cylinder head 14 is secured to the cylinder block 11. A delivery valve 15 is mounted in the cylinder head 14 and is normally biased against the cylinder block by a spring which is located within a bore 16 in the cylinder head, so that the delivery valve closes the end of the cylinder 12. The delivery valve 15 is surrounded by a gallery 17 which is connected via passages 18 in the cylinder blocks 11 and pump body 8 to corresponding galleries surrounding the delivery valves of the other pumping assemblies. The passages 18 are connected by a branch passage 19 to the delivery outlet 7.

[0019] In use, as each pump plunger 13 is driven towards associated cylinder head 14 fuel in the pumping chamber is pressurised and when the pressure of fuel within the cylinder 12 exceeds that in the gallery 17 and passages 18 the delivery valve 15 will open to allow fuel to flow from the pumping chamber 12 to the passages 18 and eventually via branch passage 19 to the outlet 7. The delivery valves 15 automatically close under the influence of the associated springs when the pumping plungers reach top dead centre. Closure is assisted by the pressure difference resulting from the plunger beginning to move inwards after top dead centre.

[0020] Each plunger 13 is connected to an associated tappet assembly 20. Each tappet assembly 20 comprises a tappet shell 21 which is slidably mounted in a bore 22 provided in the body 8. A roller 23 is rotatably mounted on a shaft 24 which is secured to the tappet shell 21. At the end thereof remote from the shaft 5 each tappet shell 21 is counterbored to provide a shoulder 25. A slipper 26 is mounted within the counterbored portion of each tappet shell with a thrust surface of the slipper in engagement with the shoulder 25. The slipper is somewhat smaller in diameter than the counterbore in the tappet shell so that some lateral movement of the slipper relative to the tappet shell is possible. Each slipper 26 defines a spherical seat 27 which is engaged with a complementary spherical surface 28 provided on a head 29 of the associated plunger 13. As an alternative to part-spherical surfaces, part-conical surfaces may be used. Each plunger 13 is secured to its associated tappet shell by any appropriate method that preserves the necessary freedom for articulation and achieves adequate sealing. For example a resilient circlip, with or without one or more washers may be used. In use substantial separation of the pump plunger 13 from its associated tappet shell is not possible.

[0021] It will be noted that the effect of the slipper arrangement referred to above is that axial thrust loading can be transferred from the tappet shell to the pumping plunger 13 but some transverse movement of the tappet shell relative to the plunger 13 is possible. Accordingly, a degree of eccentricity and misalignment of the cylinder 12 relative to the bore 22 can be accommodated by movement of the slipper relative to the tappet shell.

[0022] In use, if a plunger is in its bottom dead centre position rotation of the shaft 5 will cause the cam 6 to act on the roller 23 which will in turn drive the tappet shell and with it the associated plunger 13 radially outwardly towards its top dead centre position. Such movement will cause delivery of the fuel to the outlet 7 as described above.

[0023] In order to return each pump plunger from its top dead centre position to its bottom dead centre position means are provided for supplying fluid under pressure to a chamber 30 which is defined in part by the bore 22, in part by the radially outer side of the tappet assembly, and in part by the cylinder block 11. Such fluid under pressure can conveniently be in the form of pressurised lubricating oil derived from the lubrication system of the engine served by the illustrated pump. Such lubricating oil can be supplied via an inlet fitting 31 and delivered via drilling 32 and slots 33 to the chambers 30.

[0024] It will be appreciated that pressurised lubricating oil within the chambers 30 will act over the area of the tappet assemblies (less the area of the pump plunger 13) to produce a force on the pump plunger 13 in the radial inward direction. When any particular roller 23 is not being driven by the cam 6 the oil pressure within the associated chamber 30 will cause the roller 23 to remain in contact with the cam 6 as the associated plunger is moved from its top dead centre to its bottom dead centre position.

[0025] It should be appreciated that in the illustrated pump no inlet valve is provided on or adjacent to the cylinder head 14. Rather, one or more passages 34 extends from a fuel gallery 35 defined between the cylinder block 11 and cylinder head 14 to a point in the bore 12 just radially outwardly of the bottom dead centre position of the radially outer end of the pumping plunger 13. Fuel under slight super-ambient pressure is maintained within the gallery 35 by a transfer pump. As the pump plunger moves from top dead centre towards bottom dead centre the delivery valve 15 will close and thereafter a vacuum will be generated within the cylinder 12. As soon as the radially outer end of the pump plunger 13 clears the port 36 at the juncture of the passage 34 and the cylinder 12 fuel will flow from the gallery 35 through the passage 34 into the cylinder 12 under the combined effects of the vacuum created within the cylinder 12 and the super-ambient pressure at present in the gallery 35.

[0026] Engine oil pressure typical at engine idle speeds will provide sufficient force, when applied over the area of the tappet assembly, to drive the plunger 13 as required from top dead centre to bottom dead centre.

[0027] It will be appreciated that as the pumping assemblies operate the volume of the associated working chambers 30 will vary cyclically. As a particular pump plunger is driven from bottom dead centre towards top dead centre the volume of the associated working chamber 30 will decrease, but simultaneously the volume of the chamber 30 of at least one of the other pumping assemblies will increase. Accordingly, oil will tend to flow through the drilling 32 from one chamber 30 to another as the pump operates. There may be some variation in the total volume of the chambers 30 as the pump operates and accordingly some small net flow of oil into or out of the inlet 31 may occur.

[0028] Preferably, some lubricating oil is permitted to escape from the chambers 30 into the cam chamber 37 so as to lubricate of the tappet assembly bores 22 and to lubricate the rollers 23 and cam 6. Such escaping oil will additionally lubricate the bearings 9,10 and is preferably permitted to flow back into the crankcase of the engine to which the fuel pump is attached via the front bearing 10. A small net loss of lubricating oil past the tappet assemblies into the cam chamber 37 is in fact desirable in that it will allow a flow of lubricating oil through the pump and thereby reduce any tendency for the lubricating oil to overheat as a result of being shunted into and out of the chambers 30 as the pump operates.

[0029] It will be noted that the above described embodiment of the invention not only provides a simple and reliable means for returning the pump plungers from their top dead centre to bottom dead centre positions, but provides high quality lubrication to the various internal components of the pump assembly. Lubrication is effective by means of pressurised lubricating oil which is the ideal medium for providing such lubrication.

[0030] Whilst the invention has been described with reference to a particular embodiment thereof, it is to be understood that it is generally applicable to a wide range of positive displacement pumps, and accordingly should not be regarded as limited to the particular embodiment described. More particularly, the invention is generally applicable to any positive displacement pump in which the pumping plunger is required to be driven from top dead centre to bottom dead centre. Although the use of lubricating oil for driving the pump plungers from top dead centre to bottom dead centre offers a number of significant advantages it is to be understood that the invention is not limited to such a fluid.

[0031] The pressurised fluid required to drive the pump plungers may be obtained from any suitable source. If desired, a pressure accumulator may be used to receive variations in the total volume of the pressurised fluid system as the pump operates. The invention may be applied to a pump having only a single pumping plunger, in which case a pressure accumulator having a volume sufficient to accommodate the entire displaced volume of working fluid will be required. Such a pressure accumulator could be powered by means of a spring which would, in effect, then drive the pump plunger using the hydraulic fluid as an operating medium. Such an arrangement would be akin to having a spring directly driving the pump plunger in the filling direction, but would not impose the design constraints associated with the use of a spring directly for this purpose.

[0032] In appropriate circumstances, use of a non-return valve, in or near inlet 31, would permit the accumulator to determine an operating pressure which exceeds the oil supply pressure during part of the accumulator piston's reciprocation, such a higher pressure would allow the pump to run at higher speeds, by coping with increased tappet acceleration, or would allow for the increased acceleration consequent on employing a non-circular cam. Such a cam could have one or more lobes. It could be arranged to produce a slow pumping action, for reduced drive torque, and then a rapid return stroke.

[0033] Figures 4-6 illustrate schematically an alternative embodiment to the invention. In this embodiment three pumping assemblies 102, 103 and 104 which are substantially identical to each other are provided axially spaced apart along a camshaft 105. The camshaft 105 has three cams 106 located 120° out of phase with each other. Each cam is associated with a respective one of the pumping assemblies 102,103,104. The camshaft 105 is supported in a pump body 108 by a front bearing 109 and a rear bearing 110. In use, the pump body 108 may be secured to an internal combustion engine and an appropriate rotary drive from the engine is used to rotate the camshaft 105.

[0034] Each of the pumping assemblies 102,103,104 is substantially identical to each other and is substantially identical to the pumping assemblies 2,3,4 of the embodiment of the invention shown in Figures 1-3. In the interests of brevity only the pumping assembly 102 will be described in detail.

[0035] The pumping assembly 102 comprises a cylinder block 111 which defines a pumping chamber 112. A pumping plunger 113 is slidably mounted in the cylinder 112 and, in use, is reciprocated along the cylinder to vary the volume of a pumping chamber defined by the pumping plunger and the cylinder block 111. A delivery valve 115 is provided to permit discharge of pumped fluid from the pumping chamber. Suitable passages provided in the cylinder block 111 interconnect the discharge valves 115 of the respective pumping assemblies 102, 103 and 104 and provide a discharge passage for pumped fluid.

[0036] Each pumping plunger 113 is connected to an associated tappet assembly 120. The tappet assembly, and the means of connection between the tappet assembly and the pumping plunger, may conveniently be as described above in relation to Figure 1. However, the invention is not limited to such an arrangement and any suitable arrangement may be made to connect the pumping plunger to the tappet assembly. A roller 123 is carried by the tappet assembly 120 and engages the surface of the cam 106.

[0037] A working chamber 130 is defined between the tappet assembly 120 and the cylinder block 111. It will be noted that the working chamber 130 has a volume which increases as the volume of the pumping chamber increases, and decreases as the volume of the pumping chamber decreases.

[0038] Suitable means are provided for supplying a working fluid under pressure to the working chambers 130. Conveniently, the working fluid can be pressurised lubricating oil and the means for delivering the working fluid can be a lubricating oil pump associated with the engine to which the high pressure pump of the present invention is attached. It is to be understood however that any suitable working fluid, supplied by any suitable means, may be used to pressurise the working chamber 130. The working fluid acts on the tappet assembly 120 over a working area substantially equal to the difference between the diameter of the bore 122 in which the tappet assembly 130 works and the area of the cylinder 112 in which the pumping plunger 113 works. This area is large compared with the working area of the pumping plunger 113 and the application of lubricating oil as a working fluid at a moderate pressure is able to produce a sufficiently large force on the pumping plunger 113 to move the pumping plunger from its second (top dead centre) position to its first (bottom dead centre) position. During forward (pumping) strokes of the pumping plunger it is driven from its first (bottom dead centre) to its second (top dead centre) position by its associated cam 106. Preferably, during this forward stroke of the pumping plunger working fluid under pressure remains within the working chamber 130. The force available from the cam is sufficient to overcome the force created by the pressurised working fluid within the working fluid chamber 130 and, in addition, provides the necessary force to drive high pressure fluid from the pumping chamber of the pump.

[0039] The chambers 130 may conveniently be combined as a trough to permit fluid exchange with low flow resistance. To this end, a suitable connection may be provided between the chambers by means of drillings and/or slots in a manner similar to that of the embodiment of Figures 1-3.

[0040] As with the embodiment of Figures 1-3, an accumulator may be provided to maintain working fluid pressure in the working chamber and to receive fluid from the working chambers as their volume varies in use.

Claims

1. A positive displacement pump comprising a cylinder (12), a pump plunger (13) slidably mounted in the cylinder to define therewith a pumping chamber, the pump plunger having a first position relative to the cylinder corresponding to the maximum volume of the pumping chamber and a second position relative the cylinder corresponding to the minimum volume of the pumping chamber; and drive means (6,23,20) for driving the pumping plunger (13) in a forward direction from the first position towards the second position to reduce the volume of the pumping chamber to effect delivery of a pumped fluid, characterised in that: a piston (20) is coupled to the pumping plunger (13); the piston is slidably mounted in a bore (22) defined in the pump so as to define a working chamber (30) the volume of which increases as the pumping plunger moves in a return direction from the second position towards the first position; and means are provided for supplying working fluid under pressure to the working chamber (30) to generate a force on the piston (20) to move the pumping plunger (13) in the return direction from the second position to the first position.

2. A positive displacement pump according to claim 1 characterised in that the means for supplying working fluid under pressure is adapted to supply work-

ing chamber at all times when the pump is in operation and the drive means is effective to move the pumping plunger (13) against the force generated by the working fluid during forward strokes of the pump plunger.

3. A positive displacement pump according to claim 1 or claim 2 characterised in that the means for supplying working fluid under pressure comprises means for supplying lubricating oil under pressure.

4. A positive displacement pump according to claim 3 characterised in that the means for supplying lubricating oil under pressure comprises a lubricating oil pump of an internal combustion engine.

5. A positive displacement pump according to any preceding claim characterised in that the piston (20) is formed by a tappet assembly which, as well as performing its function as a piston, acts to transmit force from a drive cam (6) to the pumping plunger (13) during forward strokes of the pumping plunger.

6. A positive displacement pump according to claim 5 characterised in that a leakage path is defined past the tappet assembly (20) so as to allow lubricating oil to escape from the working chamber (30) to lubricate internal components of the pump.

7. A positive displacement pump according to claim 5 or claim 6 characterised in that each pumping plunger (13) is formed with a head (29) which is secured to and forms part of the tappet assembly, and the head (29) closes the interior space of the tappet assembly and thereby allow the tappet assembly to act as a piston.

8. A positive displacement pump according to claim 7 characterised in that he tappet comprises a tappet shell (21) within which the head (29) is received and a slipper (26) is interposed between the head of the plunger and the tappet shell.

9. A positive displacement pump according to claim 8 characterised in that the slipper (26) includes a flat face that engages a complementary flat face of the tappet shell and a part-spherical (27) or part-conical face that engages a complementary part-spherical face (28) of the pumping plunger head (29).

10. A positive displacement pump according to any preceding claim characterised in that a plurality of pumping plungers (13) is provided and the working chambers (30) associated with the respective pumping plungers are interconnected to allow working fluid to flow between the working chambers (30) as the respective pumping plungers reciprocate.

11. A positive displacement pump according to any preceding claim characterised in that an accumulator is provided to maintain working fluid pressure and to receive surplus working fluid as the total volume of the working chambers (30) varies during rotation of the drive shaft of the pump

Fig 1

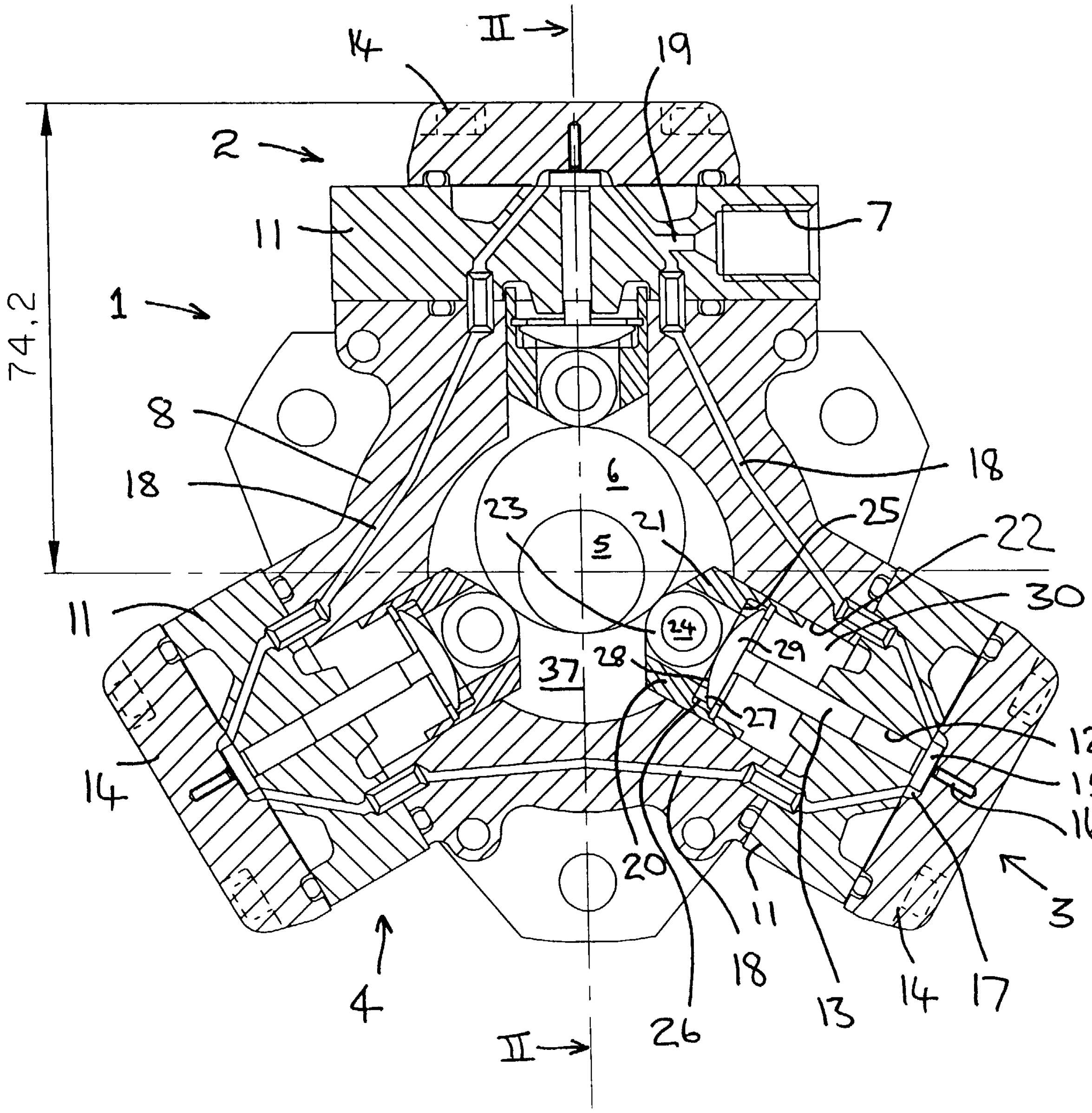

II
14
19
2
7
11
1
74,2
8
18
6
18
23
21
25
22
5
11
24
30
29
37
28
27
12
15
14
16
20
3
11
18
4
26
13
14
17
II

Fig 2

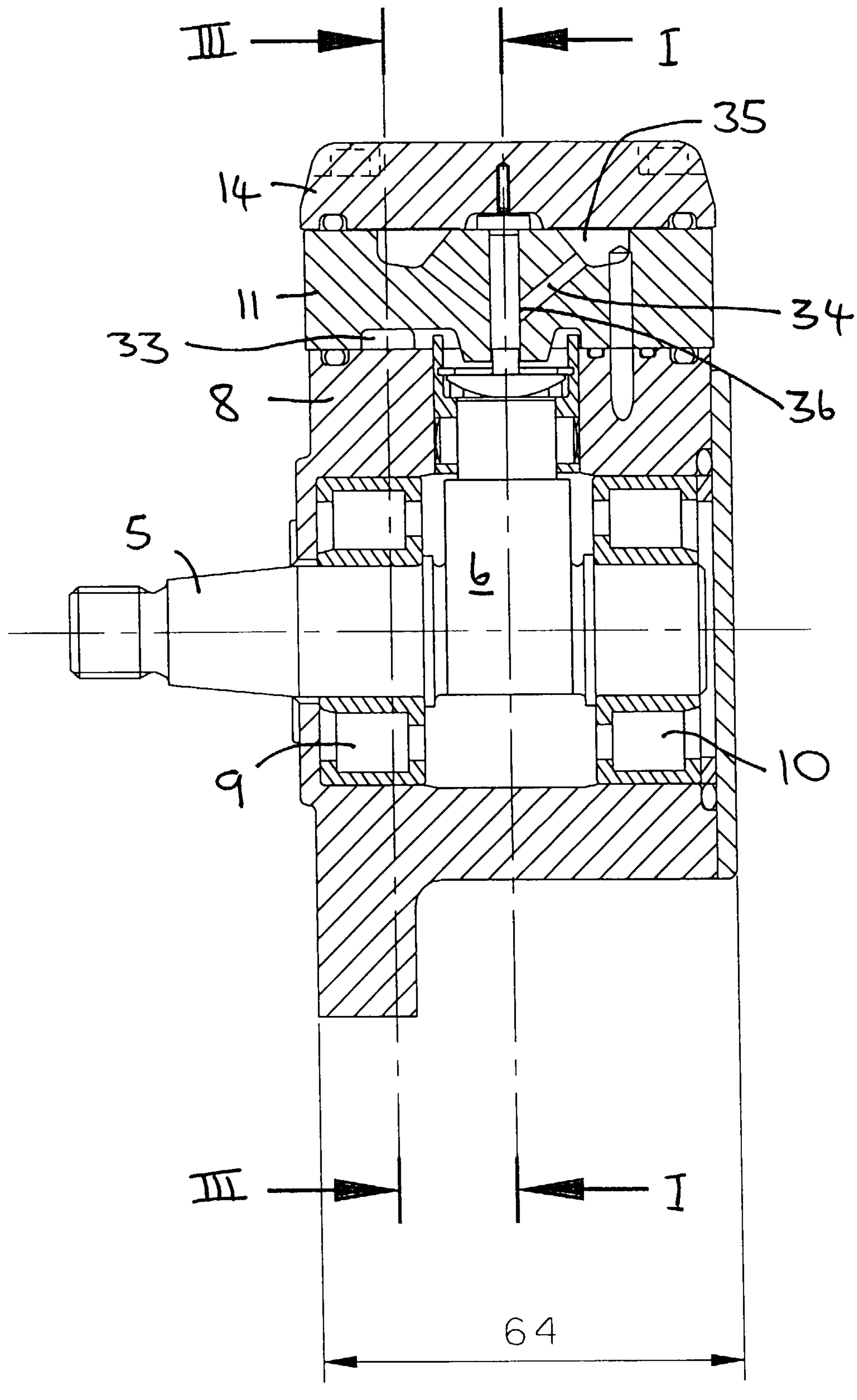
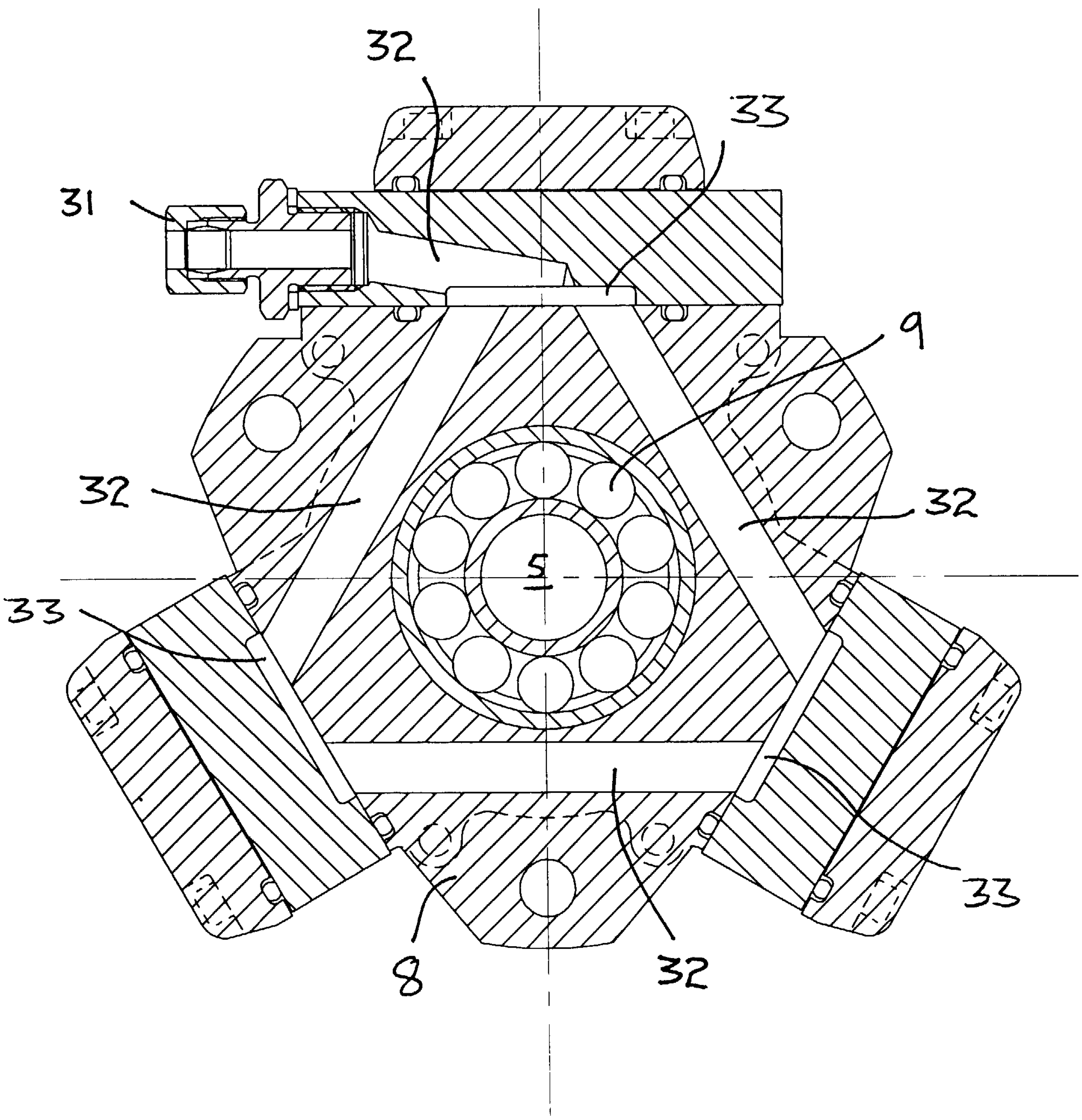


Fig 3



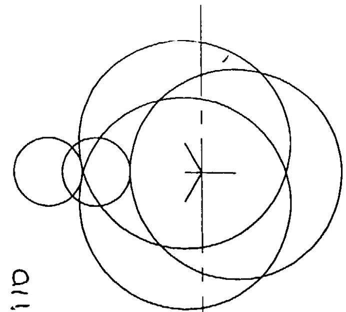


Fig 6

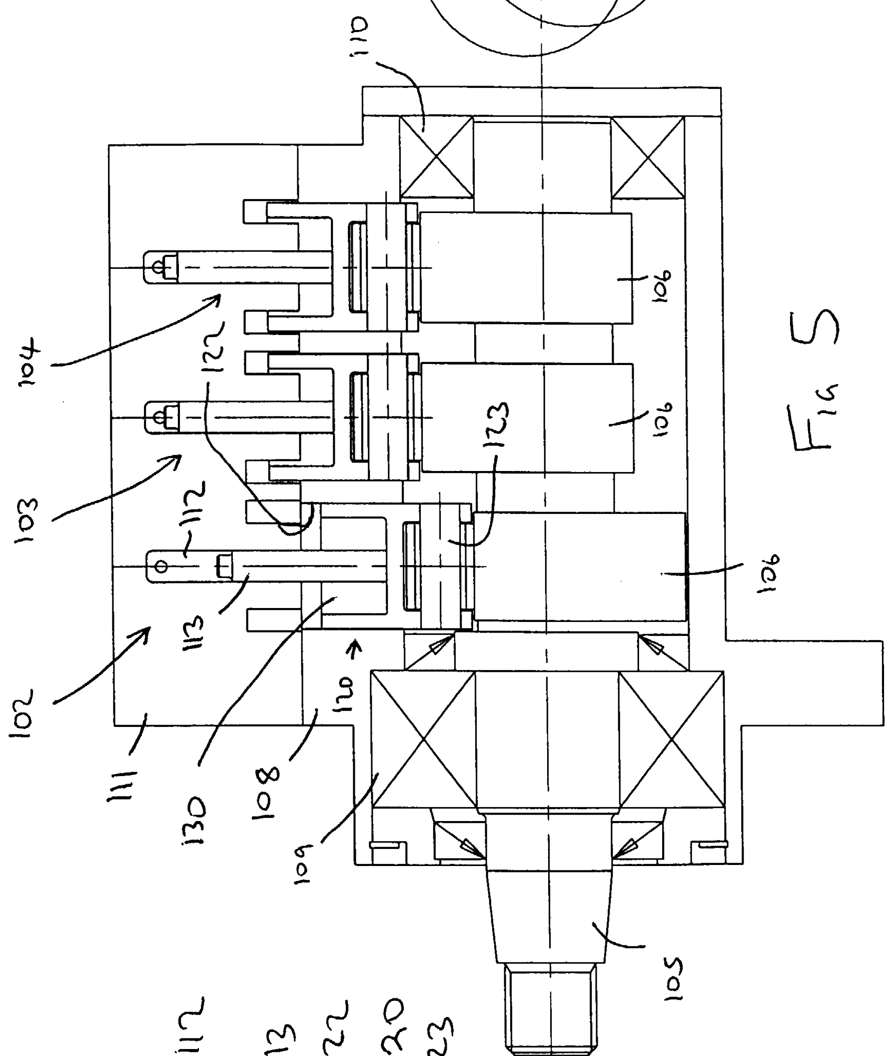


Fig 5

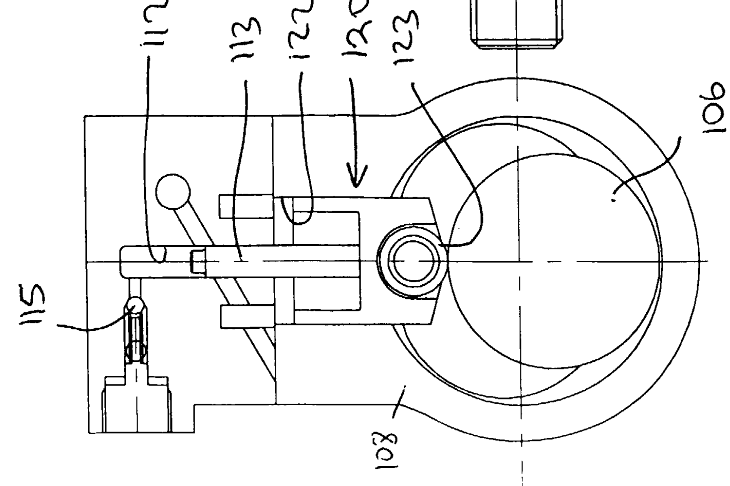


Fig 4