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(54) PISTON PUMP

(71) We, SHIMADZU SEISAKUSHO LTD, a Japanese Company of 378, Ichinofunairi-cho, Kawaramachi-Nijo Sagaru, Nakagyo-ku, Kyoto, Japan, do hereby declare the invention,

for which we pray that a patent may be granted to us, and the method by which it is performed, to be particularly described in and by the following statement:—

This invention relates to a piston pump.

Generally speaking, the piston or plunger type of fluid pump has the advantage of being controllable as to its quantity of discharge fluid in comparison with the gear pump. Examples of such piston pumps may be seen in U.S. Patent No. 2990781 and U.S. Patent No. 3236189. Almost all these pumps are of the axial plunger type wherein a cylinder block (or cylindrical barrel) is provided with a plurality of elongated cylindrical bores arranged in a circle around the driven shaft, the bores extending in directions parallel to the driven shaft, and a plurality of reciprocable plunger assemblies each comprising a pair of slidable plunger members inserted into each of the cylindrical bores, the pumping action being produced by the relative rotation between the group of plunger members and an inclined disc or swashplate fixedly mounted on the driven shaft.

The object of the invention is to provide an improved piston pump.

According to the invention there is provided a piston pump comprising:

a) a casing and a closure plate defining an enclosed space within the pump;

b) a truncated conical pintle carried by a slide block itself supported by the closure plate for sliding transversely of the axis of the pintle and the pintle being arranged to protrude into the enclosed space;

c) two arcuate grooves located oppositely to each other on the conical surface of the pintle, an inlet passage and an outlet passage passing through the closure plate, and a pair of passageways passing through the pintle and the slide block whereby one of the arcuate grooves communicates with the inlet passage and the other arcuate groove communicates with the outlet passage;

d) a cylinder block rotatably fitted on the conical surface of the pintle and having a plurality of cylinders radiating from the conical surface;

e) a plurality of pistons inserted one into each cylinder of the cylinder block;

f) a cylindrical holder having a plurality of flat faces in the interior wall thereof, each face being in contact with the outer end face of a respective one of the pistons;

g) a driven shaft for rotating the cylinder block and the holder together round the conical surface of the pintle; and

h) means for sliding the slide block transversely of the pintle, thereby to adjust the eccentricity of the pintle with respect to the axis of the driven shaft.

Preferably the slide block is formed as a member whose section is trapezoidal and a port arrangement is provided on the inclined surface of the slide block opposed to the one of the arcuate grooves communicating with the outlet passage, the pintle and the slide block being thereby kept in pressure balance.

It is further preferred that the means for sliding the slide block includes a couple of piston mechanisms arranged opposite each other at respective end faces of the slide block, one of which mechanisms being adapted to exert a larger thrust than the other, the piston mechanism having the larger thrust being connectable with a drain passage through a relief valve, the arrangement being such that the slide block is slid by means of the larger thrust piston mechanism to make the pintle eccentric from the driven shaft, until the discharge pressure of fluid rises over the opening pressure of the relief valve when the relief valve opens and the piston mechanism having the larger thrust is connected to the drain passage and the slide block is returned to its original position before lsiding by means of the piston mechanism having the smaller thrust.

It is possible that the distance over which the slide block is made to slide by means of the piston mechanism having larger thrust, that is to say the eccentric distance of the pintle, can be adjusted by manually increasing the thrust of the piston mechanism giving the smaller thrust or by increasing its thrust by the use of pressurized fluid.

In operation, the pistons held by the cylin-

der block and the cylindrical holder rotate around the conical surface of the eccentric pintle, thereby each cylinder is connected alternately to the two arcuate grooves formed on the conical surface of the pintle, forcing each piston to reciprocate in upward and downwaard directions in the cylinder to make a pumping action.

To held understanding of the invention, a specific embodiment thereof will now be described with reference to the accompanying drawings in which:—

Figure 1 is a longitudinal section view taken on line I–I in Figure 3, of a piston pump according to the invention;

Figure 2 is a sectional view taken on line II–II in Figure 1;

Figure 3 is a plan view, partly broken away to show a pintle and a slide block, of the piston pump of Figure 1;

Figure 4 is a left side elevational view of the pump;

Figure 5 is a plan view showing the pintle and the slide block, of the piston pump of Figure 1;

Figure 6 is a left side elevationa view of the block of Figure 5;

Figure 7 is a right side elevational view of the block of Figure 5;

Figure 8 is an elevational view showing the inclined surface of the slide block of Figure 5; and

Figure 9 is a diagrammatic view of discharge characteristics of the pump of Figure 1.

In the pump illustrated in Figure 1, each piston is not arranged in the axial direction, but is arranged radially with a tilt angle. The casing 1 and a closure plate 2 define an enclosed space within the pump P. A pintle 3 is held by a slide block 4 supported by the plate 2 and protrudes into the enclosed space. As illustrated in Figures 5 and 7, the pintle 3 is formed as a member which is of circular truncated conical form, and the slide block 4 is formed as a member whose section is trapezoidal. The slide block 4 is slidably supported by the plate 2 slidably with the inclined surfaces 4*a* and 4*b* acting as the guiding surface.

Two arcuate grooves 5 and 6 are formed opposite to each other, on the conical periphery of the pintle 3 over the angular range of approximately 130 degrees. These arcuate grooves 5 and 6 communicate respectively with an inlet passage 9 and an outlet passage 10 in the closure plate 2 through passageways 7 and 8 in the slide block 4 and the pintle 3. On the inclined surfaces 4a and 4b are formed ports 11 and 12 having a predetermined area, including the opening aperture of the passageways 7 and 8 and communicating the arcuate grooves 5 and 6 to the inlet passage 9 and outlet passage 10, respectively. The predetermined areas of the ports 11 and 12 correspond to the projected area of pistons in communication with the arcuate groove 6, that is, those amongst the pistons mentioned hereinafter which are discharging fluid. Further, the predetermined area is determined in consideration of the area required for proper communication of the passageways 7 and 8 with the inlet passage 9 and outlet passage 10, respectively, without permitting any overlapping of them, while sliding of the slide block 4. For the space 11 opposite the arcuate groove 5 communicating with the inlet passage 9, it is enough if the latter condition mentioned above is satisfied. Balancing grooves 13 and 14 are formed around the ports 11 and 12, which grooves 13 and 14 are provided for sealing any fluid leaked through the ports 11 and 12 and to lubricate for sliding of the slide block 4 on the inclined surfaces 4a and 4b.

The slide block 4 slides in such a way that there is a very slight eccentricity between the centre of the pintle 3 and the centre of a driven shaft 36 mentioned hereinafter when the slide block 4 is at the beginning of its sliding stroke, and on the other hand, there is the most eccentricity between the centre of the pintle 3 and the centre of the driven shaft when it has been slid to the full extent of its stroke. The eccentric distance "*l*" between the pintle 3 and the shaft 36 corresponds to the stroke of the pistons mentioned hereinafter, being proportioned to the quantity of discharge fluid. Therefore, it is possible to control the quantity of discharge fluid by adjusting the eccentric distance "*l*".

The sliding of the slide block 4 takes place as follows:

There are provided a couple of piston mechanisms 17 and 18 opposed to each other at both the end faces 15 and 16 of the slide block 4. The piston mechanisms 17 and 18 have respective cylinders 19 and 20 of the same diameter formed in the plate 2 and the same diameter of pistons 21 and 22 inserted thereinto, respectively, Discharge fluid is introduced into the cylinders 19 and 20 through passageways 23 and 24 from the outlet passage 10. A compression spring 25 is inserted between the piston 21 and the interior end face of cylinder 19 of the piston mechanism 17. Thus although the thrust due to discharge fluid acting on the piston 21 is equal to the thrust due to discharge flud acting on the piston 22, there arises such a nett difference of thrust between that of the two piston mechanisms 17 and 18 equal to the thrust of the compression spring 25 inserted into the piston mechanism 17. Accordingly the piston mechanism 17 containing the compression spring 25 causes the slide block 4 to slide.

There arises the most eccentric distance between the pintle 3 and the driven shaft when the slide block 4 has slid to the most by means of the piston mechanism 17 having the larger pushing force. The inside of the

cylinder 19 of the piston mechanism 17 communicates with a drain passage 26 through a relief valve 28 and a passageway 27 in this order. The opening pressure of the relief valve 28, is such that the thrust of the spring 29 corresponds to the maximum pressure of the discharge fluid, for example, 210 kg/cm^2. Therefore, when the pressure of the discharge fluid has got over the appointed opening pressure, the relief valve 28 is released, thereby the inside of the cylinder 19 of the piston mechanism 17 exerting the larger thrust is connected to the drain passage 26. A passageway consisting of the drain passage 26, passageway 27, and piston mechanism 17 communicates with the inside of the cylinder 19 due to releasing of the relief valve 28 and consequently the cylinder becomes open to a draintank (not shown in the drawings); whilst previously the cylinder 19 was pressurized due to its being connected to the outlet passage 10 through the passageway 23. Now high pressure discharge fluid is still being introduced into the piston mechanism 18 which was exerting the smaller thrust, the piston mechanism 18 will now make the slide block 4 slide to its original position where there is left a very slight eccentric distance between the pintle 3 and the driven shaft.

A cylinder block 30 is provided and has a conical inner surface conforming with the conical surface of the pintle 3. In the cylinder block 30 there are formed a plurality of cylinders 31a–31g radiating from the conical surface of the pintle 3. Each cylinder 31a–41g is slidably engaged by a respective one of the pistons 32a–32g. Each piston 32a–32g is held by means of the cylinder block 30 and a cylindrical holder 34 having a plurality of flat faces 33a–33g in the interior wall thereof which contact the outer end face of each piston 32a–32g, respectively. It is so arranged that each piston 32a–32g is always in contact with each flat face 33a–33g of the holder 34. In order to keep them so, it is usual that a compression spring (not shown in the drawings) is inserted in each cylinder 31a–31g. However, it may be possible that each piston 32a–32g can always be held by suction without providing the compression spring therein if the outer end face of each piston 32a–32g is kept tightly in sealing contact with the flat face 33a–33g of the holder 34, respectively.

In the preferred embodiments of this invention, it is so featured that the diameters of each cylinder 31a–31g and each piston 32a–32g are comparatively large, and on the contrary their overall length of stroke is comparatively short.

The cylinder block 30 and the cylindrical holder 34 together with each piston 32a–32g rotate around the conical surface of the pintle 3 integratedly there together in such a way as following:

It is so arranged that the cylinder block 30 is rotated by a transmission shaft 40 having splines 38 and 39 which are engaged with the spline 35 formed on the inner surface of the bore perforated in the centre thereof and the spline 37 formed on the inner surface of the rotating member 36^1 integrated with the driven shaft 36, respectively. The transmission shaft 40 is supported rotatably by means of a spherical bearing 42 provided in the protruding end face of the pintle 3, the shaft being urged towards the pintle 3 by a compression spring 41 provided between the driven shaft 36 and itself. The rotating member 36^1 integrated with the driven shaft 36 is supported rotatably by means of a bearing 43 between the casing 1 and itself. The cylindrical holder 34 is formed in integration with the rotating member 36^1 and is supported rotatably by means of a tapered roller bearing 44 between the casing 1 and itself. The driven shaft 36 is sealed against the outside of the casing 1 by means of a sealing means 45. The cylinder block 30 rotates around the conical surface of the pintle 3, and the holder 34 rotates with the driven shaft. When the pintle 3 is eccentric from the centre of the driven shaft 36, the cylinder block 30 rotating round the pintle 3 is also eccentric from the centre of the holder 34 and driven shaft 36, thereby each piston 32a–32g of the cylinder block 30 is made to reciprocate in the mechanism with a pumping action.

In such a condition that the slide block 4 is made to slide by means of the piston mechanism 17 having the larger thrust, the centre of the pintle 3 is made eccentric from the centre of the driven shaft 36 as shown in Figure 1, the driven shaft 36 being made to rotate by means of a drive device to rotate the cylinder block 30 together with the holder 34. In the Figure 2 position, each piston 32a–32g is reciprocating with a pumping action, each piston 32b, 32c and 32d sucking fluid gradually through the arcuate groove 5 formed on the conical surface of the pintle 3, the inlet passage 9, and the passageway 7, and each piston 32e, 32f and 32g discharging pressurized fluid (discharge fluid) gradually to the outlet passage 10 through the arcuate groove 6 formed on the conical surface of the pintle 3, and the passageway 8. In such a way as mentioned above, three or four pistons among the pistons 32a–32g suck the fluid in consecutive order through the arcuate groove 5 and other pistons among the pistons 32a–32g discharge the pressure fluid in consecutive order through the arcuate groove 6, thus, they repeat the pumping action. Part of the quantity of discharge fluid through the discharge groove 6 is introduced into the cylinders 19 and 20 of the couple of piston mechanisms 17 and 18 opposed to each other as both the end faces of the slide block 4 through the passageways 23 and 24. As shown, the thrust due to the high pressure fluid due to the discharge fluid introduced into the piston

mechanism 17 and 18 balances because the diameters of both the cylinders 19 and 20 are the same as each other.

The high pressure acting on the pintle 3 by means of the three or four pistons communicated with the arcuate groove 6 among the pistons 32a–32g is received by the port 12 provided on the inclined surface 4*a* of the slide block 4, thereby the pintle 3 and the slide block 4 are kept in pressure balance. As mentioned above, the port 12 has its area predetermined.

If the discharge pressure should have risen abnormally, that is, if any abnormal conditions should have been brought about in the continuous discharging condition as mentioned above, it is necessary to take action so as to stop the discharging at once because it is very dangerous to continue the discharging of the fluid as it is. In this case, however, it is very inefficient to stop the pump by the operator each time any abnormal conditions have occurred. Because of such a reason mentioned above, nowadays these type of pumps are usually equipped with a pressure compensation mechanism, it is the same with pumps according to this invention. As mentioned above, the pressure compensation mechanism applied to the piston pump specifically described above is as follows:

Discharge fluid is introduced into the two piston mechanisms 17 and 18 opposed to each other at both end faces 15 and 16 of the cylinder block 4, wherein any abnormally high discharge pressure will naturally raise the pressure of the fluid introduced into the piston mechanisms 17 and 18, thereby the relief valve 28 communicated with the piston mechanism 17 having the larger thrust will be released in such a way that the ball 46 is pushed down against the pushing force of the spring 29, thus, the piston mechanism 17 will be connected to the drain passage 26. As a result of this, the thrust which kept the slide block 4 slid to its full extent will be reduced abruptly, whilst the high pressure fluid is still being introduced into the piston mechanism 18. Thus, the relation between the two piston mechanisms will become reversed, thereby the slide block 4 will be returned to its original position by means of the piston mechanism 18, and the pintle 3 will be made to return to the position where there is left a very slight eccentric distance between the pintle 3 and the driven shaft 36, thereby the stroke of each piston 32a–32g of the cylinder block 30 will be nearly nothing. Thus, the pumping action, that is, sucking and discharging of the fluid will hardly be performed, resulting in decreasing of the discharging of fluid abruptly, which condition is shown in Figure 9. In this case, however, the stroke of each piston 32a–32g is usually secured to some degree because complete stopping of discharging action will cause the contacting faces or sliding faces between the cylinder block 30 and the pintle 3 or the ones between each cylinder 31a–31g and each piston 32a–32g mated respectively to be prone to seize, resulting in producing these unfavourable conditions such as abrupt rising of the temperature of fluid and so forth. Although the consideration like this mentioned above may be said to have been taken also in the conventional axial plunger pumps, it can be said that there had not been provided so far as such a passageway allowing relief of some quantity of discharge fluid therethrough produced as the result of the slight stroke of each piston. In the above described embodiment, there is provided that the piston mechanism 17 having the larger thrust is communicated with the drain passage 26 through the relief valve 28 and the passageway 27. At the same time the inside of said cylinder 19 of the piston mechanism 17 is permanently communicated with the outlet passage 10 through the passageway 23. Thus it will be seen that when the relief valve 28 opens the outlet passage 10 is connected via the passageway 23, the inside of the cylinder 19 of piston mechanism 17 and the passageway 27 to the drain passage 26, the drain passage 26 being communicated with the drain tank or possibly to the inlet passage 9. Thus, the fluid can be circulated efficiently without confining some quantity of discharge fluid.

The invention is not intended to be restricted to the details of the above described embodiment. In one alternative embodiment, for example, there may be produced a difference between the thrust of the piston mechanism 17 and that of the piston mechanism 18 by providing the two cylinders 19 and 20 and the two pistons 21 and 22 with respectively different diameters. In another embodiment, it is possible to optionally adjust the sliding distance of the slide block 4, i.e. the eccentric distance of the pintle 3, by making the piston 22 of the piston mechanism 18 having the smaller thrust slide manually or by means of the pressure of another fluid. Thus, the quantity of discharge fluid can be controlled optionally.

The above described piston pump has the advantage that the diameter of each piston and each cylinder in the cylinder block can be made larger without enlarging the external shape of the pump housing whilst the overall length of stroke can be made shorter, making for a larger quantity of discharge fluid. Thus, collaterally the friction between each piston and the interior surface of its cylinder can be reduced and consequently their wear can be reduced.

Further, the piston pump has the feature that it has no mechanical energy loss due to a larger area of sliding surface as seen in the sliding surface of the piston and inclined disc of a conventional axial plunger pump.

Further, the piston pump has the advantage of being capable of keeping the pintle in pressure balancing with a simple mechanism, which secures smooth high speed operation as well as mechanical durability of the piston pump.

Furthermore because the pressure compensation mechanism operates in such a way that the high pressure fluid of the discharge fluid is circulated without being enclosed in the pumping chamber the temperature of fluid is not raised unfavourably.

WHAT WE CLAIM IS:—

1. A piston pump comprising:
a) a casing and a closure plate defining an enclosed space within the pump;
b) a truncated conical pintle carried by a slide block itself supported by the closure plate for sliding transversely of the axis of the pintle and the pintle being arranged to protrude into the enclosed space;
c) two arcuate grooves located oppositely to each other on the conical surface of the pintle, an inlet passage and an outlet passage passing through the closure plate, and a pair of passageways passing through the pintle and the slide block whereby one of the arcuate grooves communicates with the inlet passage and the other arcuate groove communicates with the outlet passage;
d) a cylinder block rotatably fitted on the conical surface of the pintle and having a plurality of cylinders radiating from the conical surface;
e) a plurality of pistons inserted one into each cylinder of the cylinder block;
f) a cylindrical holder having a plurality of flat faces in the interior wall thereof, each face being in contact with the outer end face of a respective one of the pistons;
g) a driven shaft for rotating the cylinder block and the holder together round the conical surface of the pintle; and
h) means for sliding the slide block transversely of the pintle, thereby to adjust the eccentricity of the pintle with respect to the axis of the driven shaft.

2. A piston pump as claimed in Claim 1, in which the slide block is formed as a member whose section is trapezoidal and a port arrangement is provided on the inclined surface of the slide block opposed to the one of the arcuate grooves communicating with the outlet passage, the pintle and the slide block being thereby kept in pressure balance.

3. A piston pump as claimed in Claim 2, in which the port arrangement includes a port having a predetermined area, including that of the passageway providing communication with said arcuate groove, corresponding to the area of the cylinders in communication with the arcuate groove.

4. A piston pump as claimed in any preceding claim, wherein the means for sliding the slide block includes a couple of piston mechanisms arranged opposite each other at respective end faces of the slide block, one of which mechanisms being adapted to exert a larger thrust than the other, the piston mechanism having the larger thrust being connectable with a drain passage through a relief valve, the arrangement being such that the slide block is slid by means of the larger thrust piston mechanism to make the pintle eccentric from the driven shaft, until the discharge pressure of fluid rises over the opening pressure of the relief valve when the relief valve opens and the piston mechanism having the larger thrust is connected to the drain passage and the slide block is returned to its original position before sliding by means of the piston mechanism having the smaller thrust.

5. A piston pump as claimed in Claim 4, in which said piston mechanism are constituted by a pair of pistons in cylinders, each pair having the same diameter, and the piston mechanism having the larger thrust has a compression spring inserted in its cylinder in order to make the difference between the force of the two piston mechanisms.

6. The piston pump as defined in Claim 4, in which the piston mechanism having the smaller thrust is adapted to have its thrust increased manually or by a source of pressure fluid to withstand the larger thrust of the first piston mechanism in order to make an adjustment of eccentricity of the pintle due to the larger thrust of the piston mechanism.

7. A piston pump substantially as hereinbefore described with reference to Figures 1 to 8 of the accompanying drawings.

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Sheet 1

Fig.1

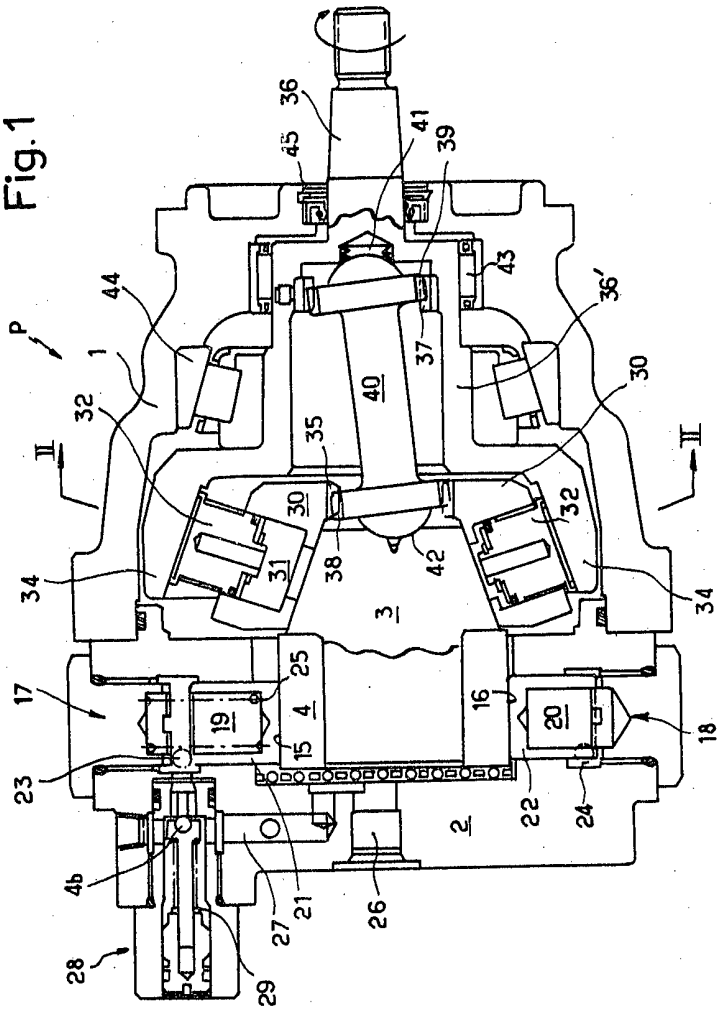

Fig. 2

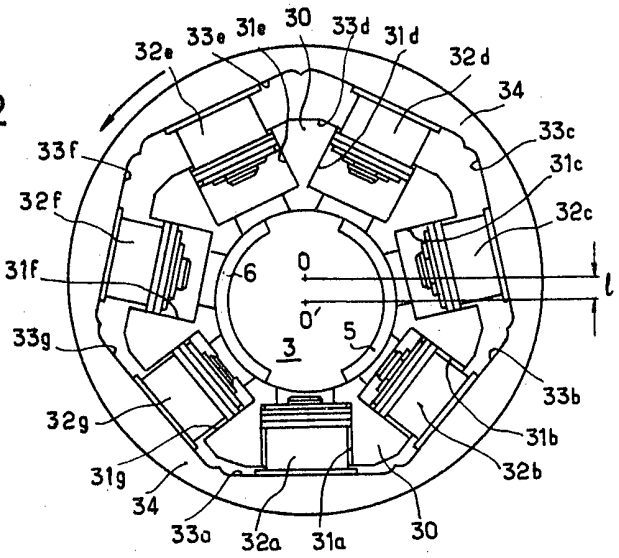
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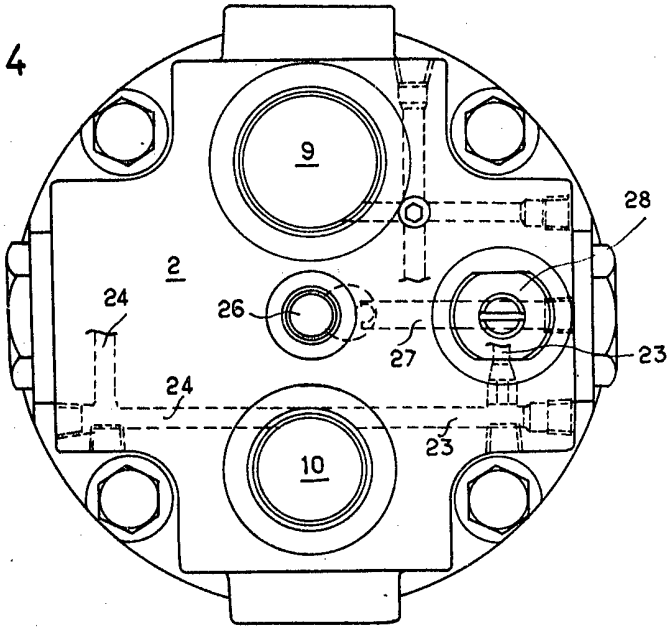
Fig. 4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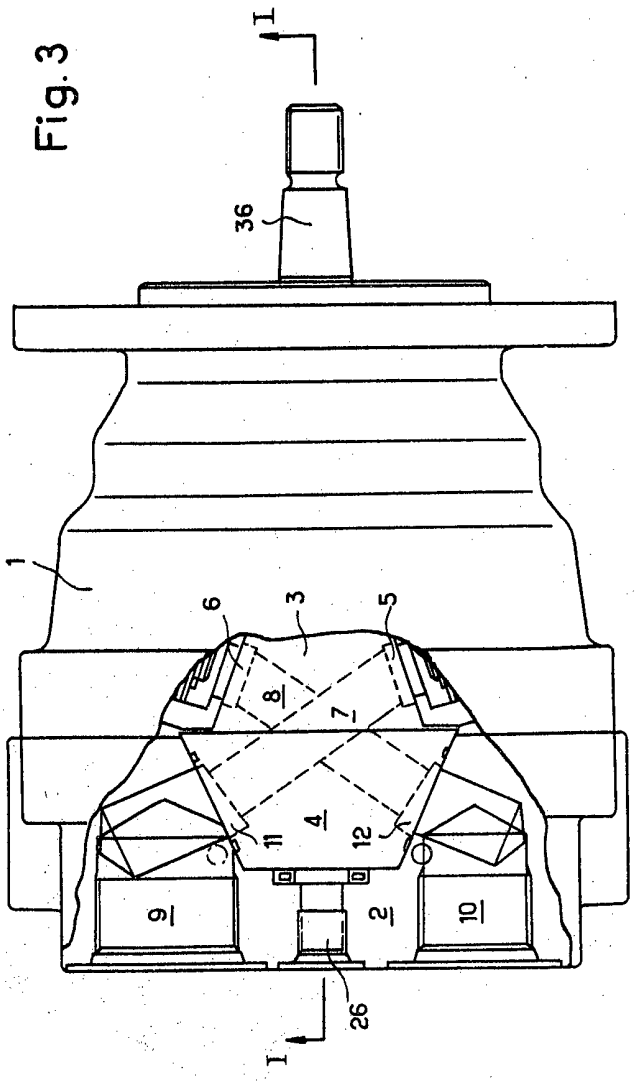
Sheet 3

Fig.3



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Sheet 4

Fig.5

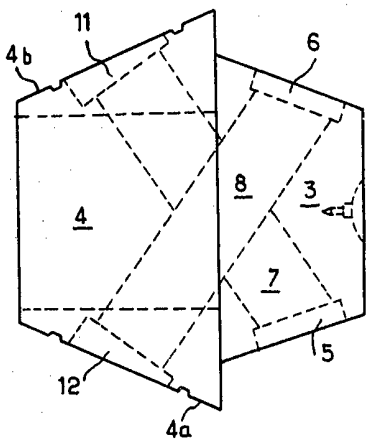


Fig.7

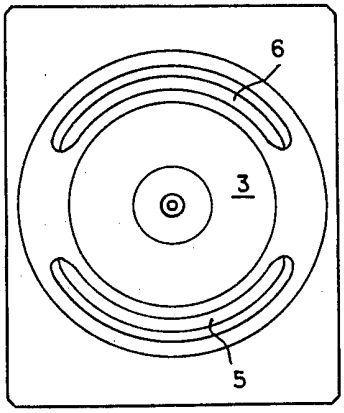


Fig.6

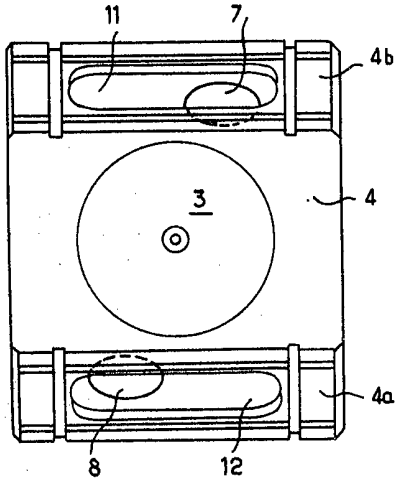


Fig.8

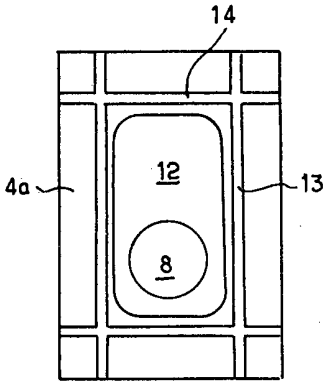
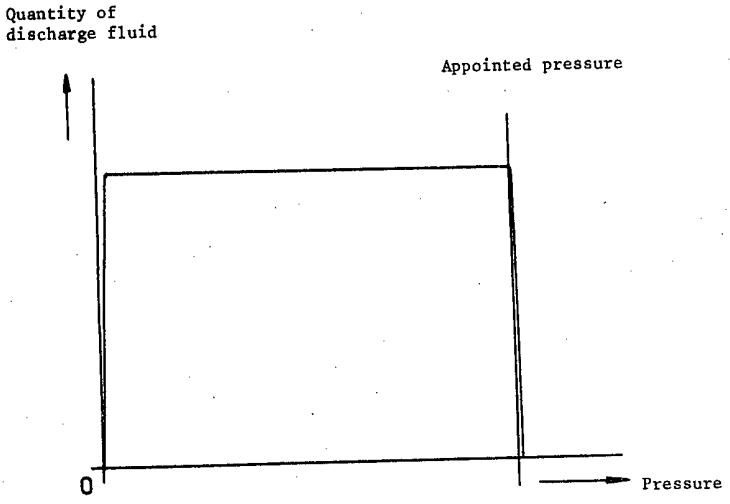


Fig. 9


Quantity of discharge fluid
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Pressure