SILENT VARIABLE DELIVERY HYDRAULIC PUMP

Filed June 4, 1962 3 Sheets-Sheet 1

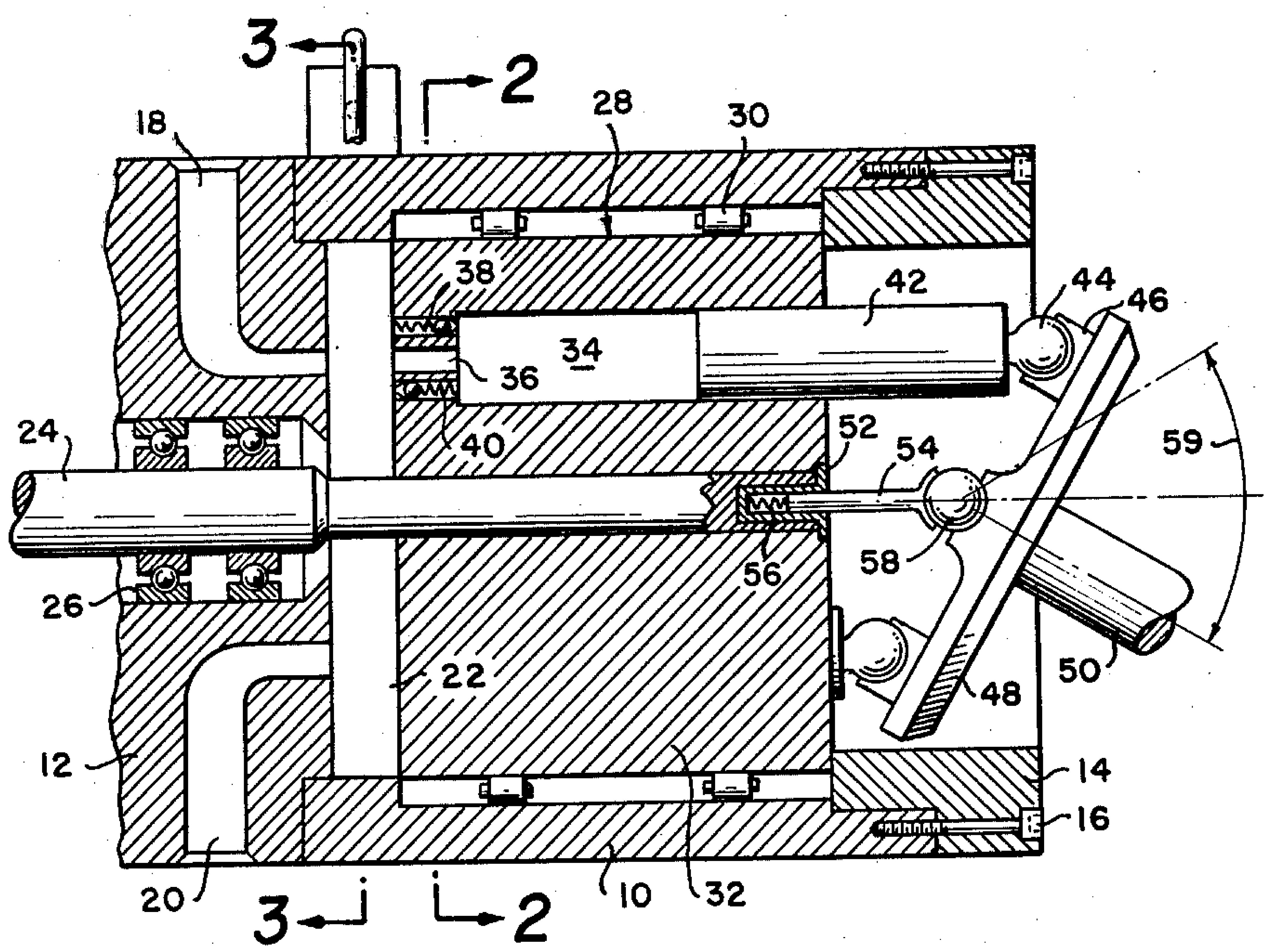

FIG. 1.

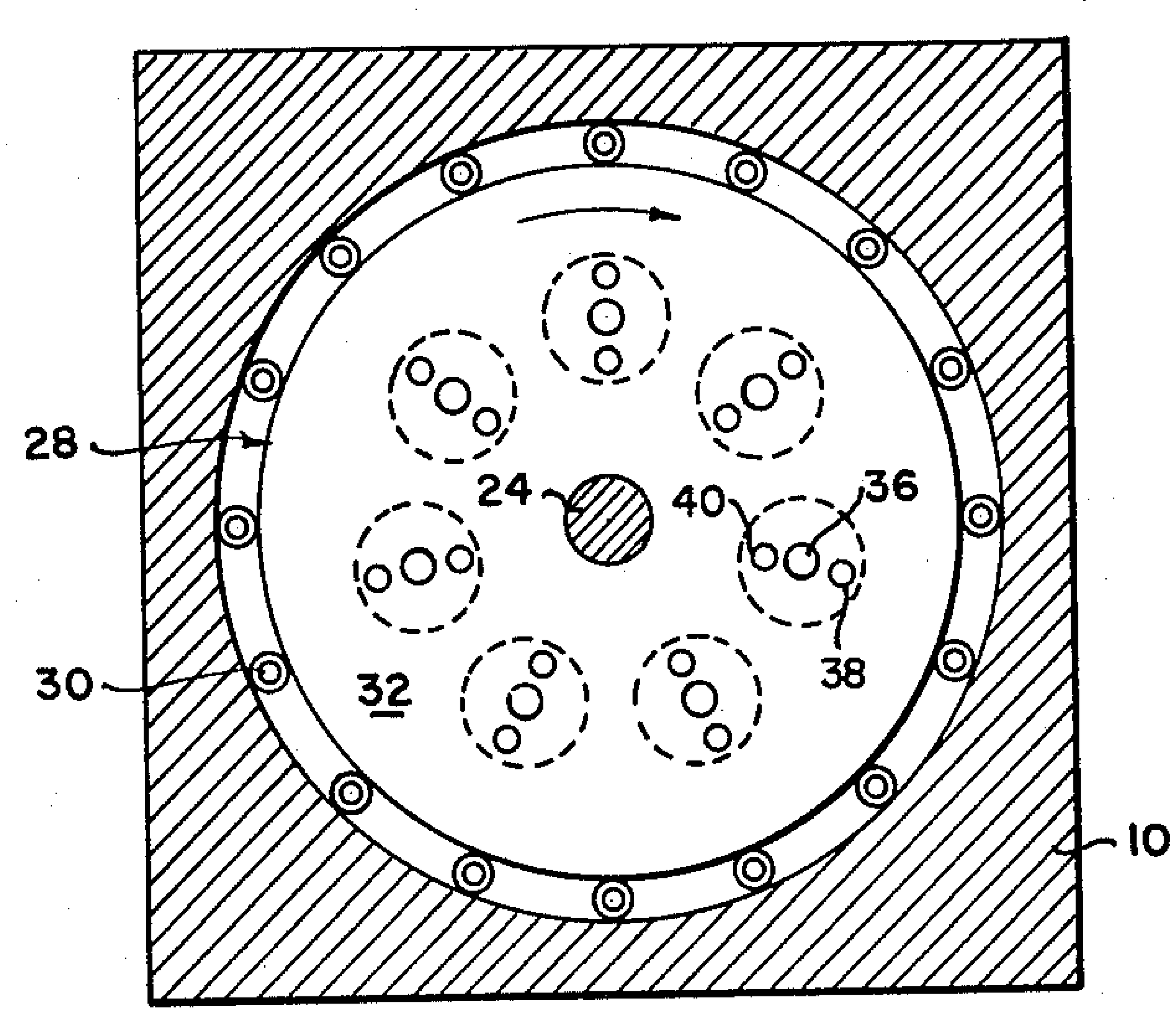

FIG. 2.

INVENTOR

FRANCIS J. SISK

BY B. L. Zangwill

ATTY.

SILENT VARIABLE DELIVERY HYDRAULIC PUMP

Filed June 4, 1962

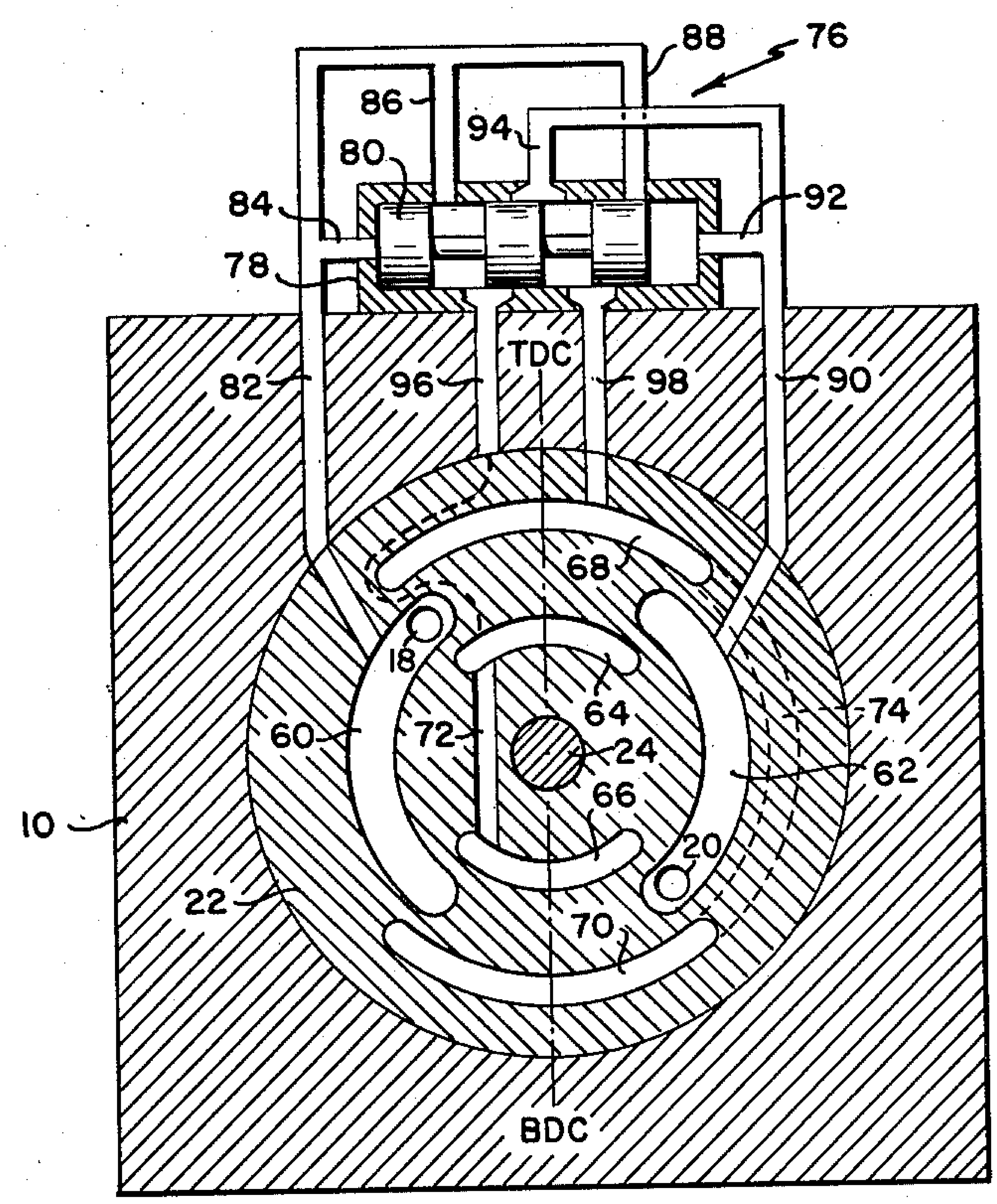

FIG. 3.

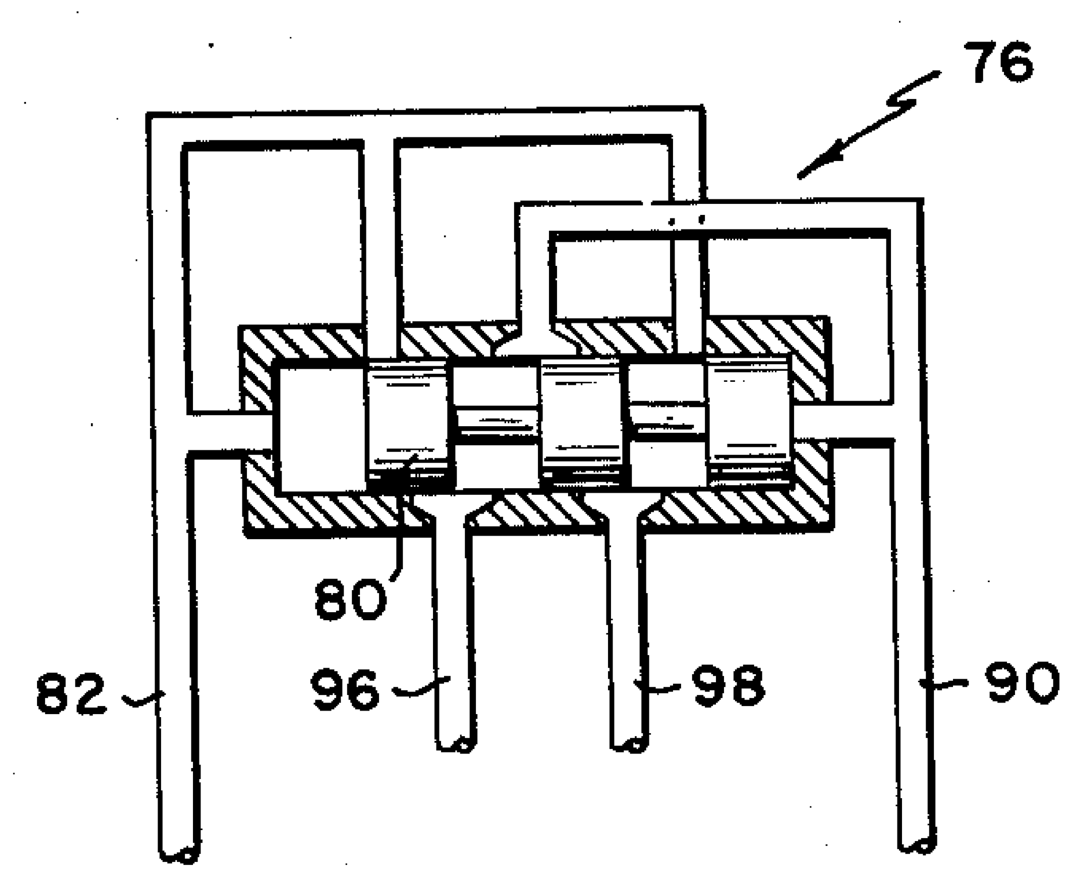

FIG. 3A.

INVENTOR

FRANCIS J. SISK

BY

B. L. Zangwill

ATTORNEY

SILENT VARIABLE DELIVERY HYDRAULIC PUMP

Filed June 4, 1962 3 Sheets-Sheet 3

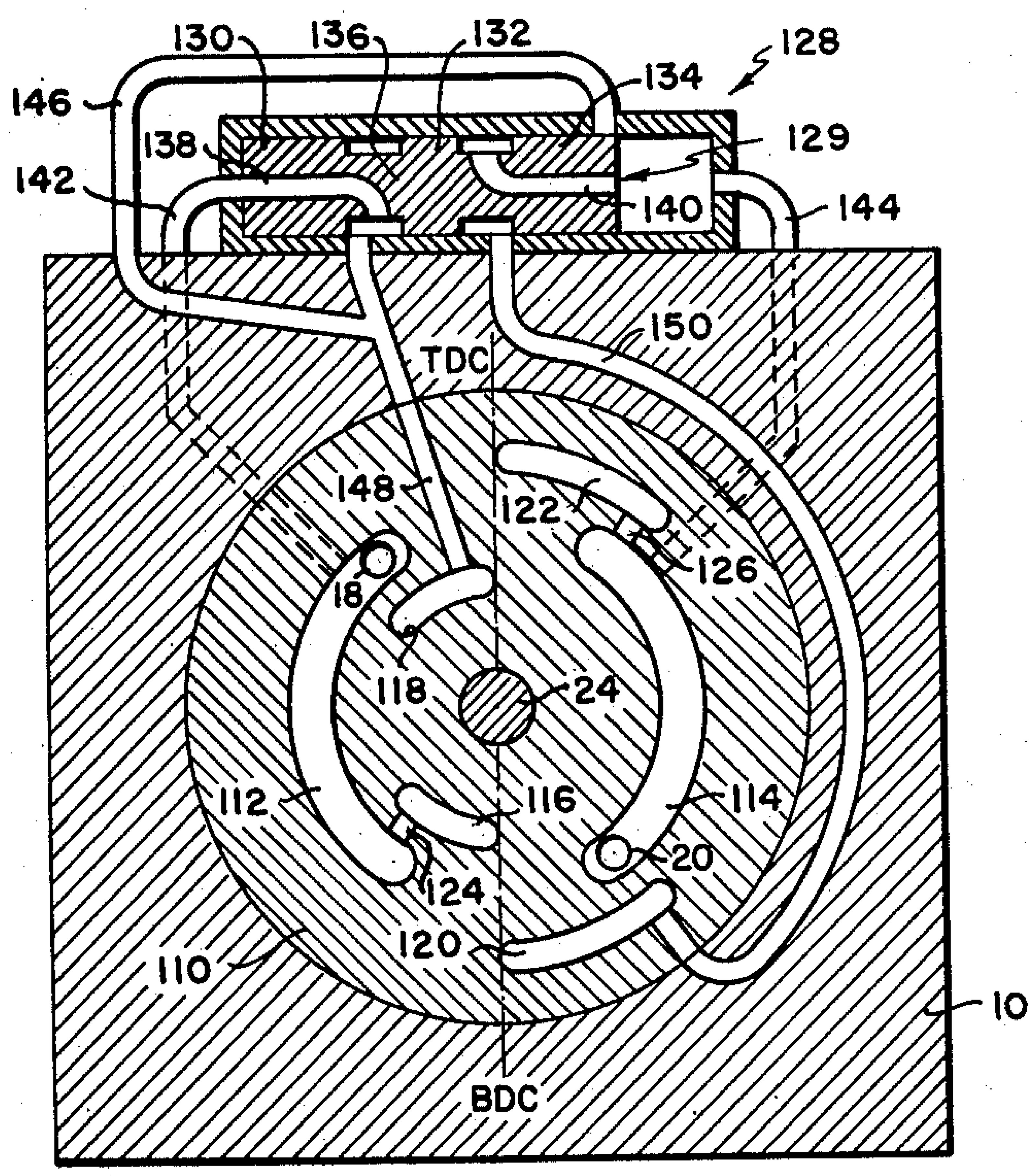

FIG. 4.

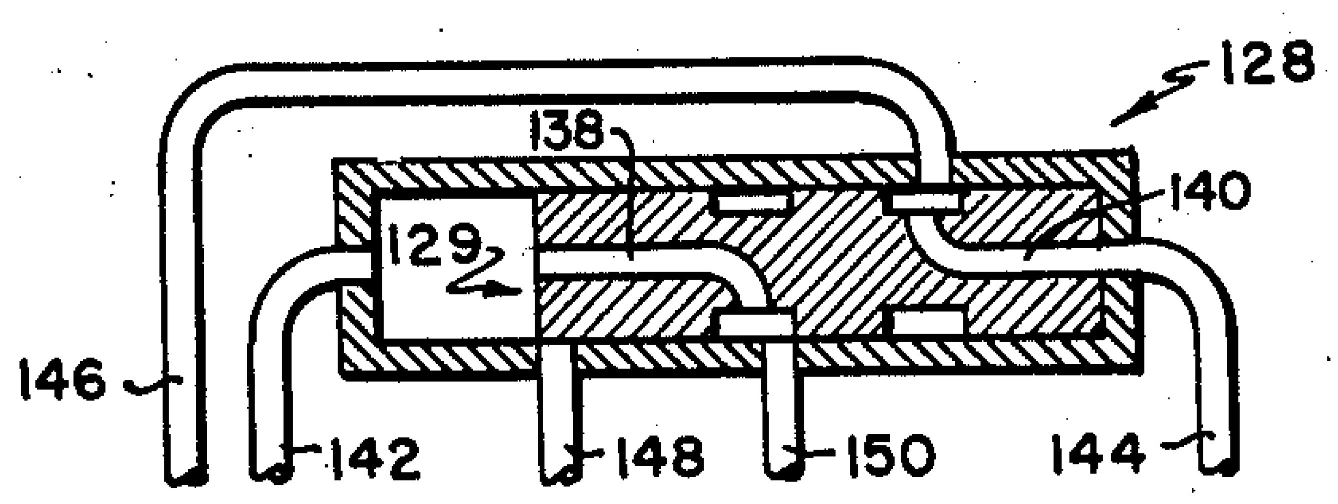

FIG. 4A

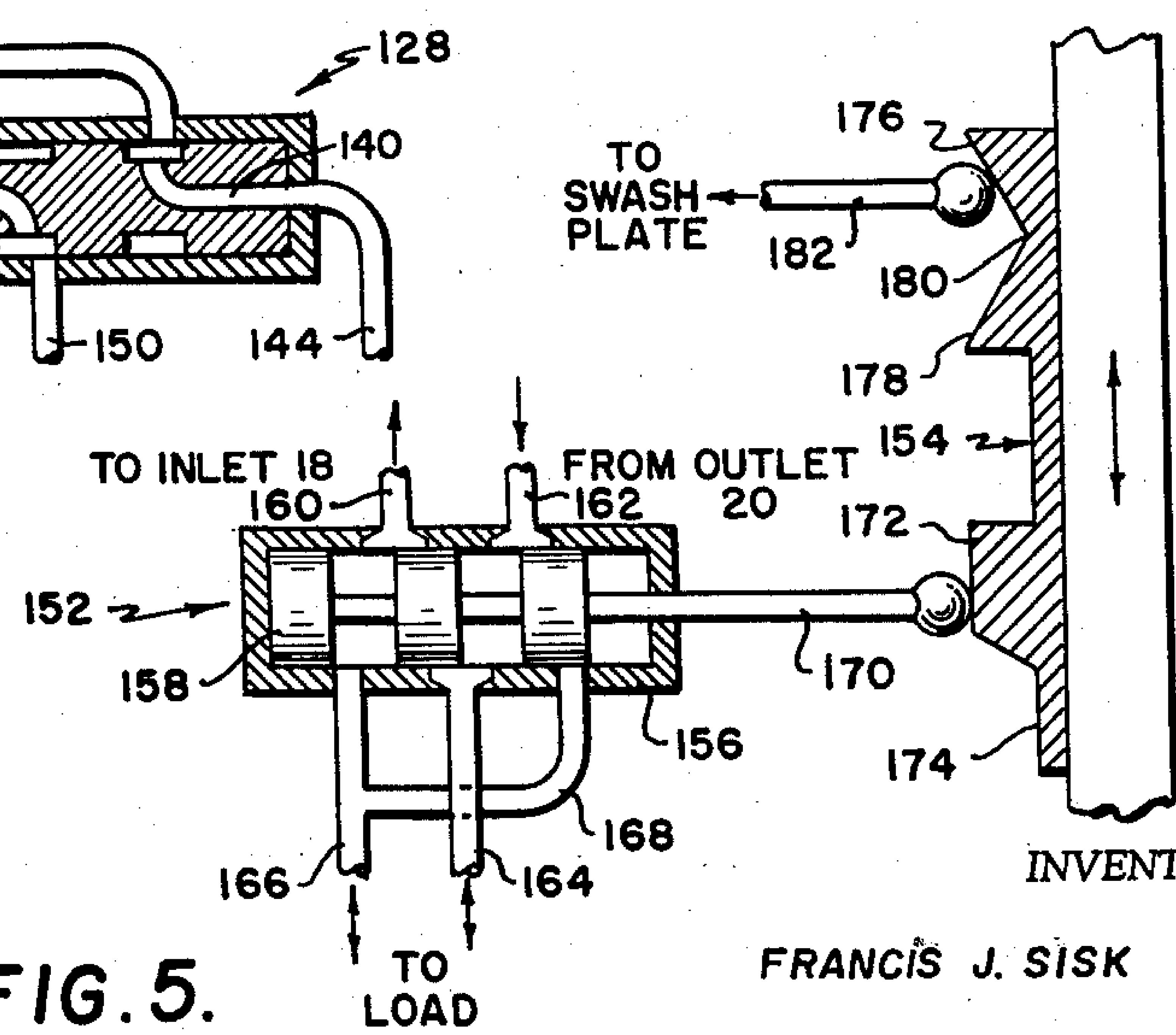

FIG. 5.

INVENTOR

FRANCIS J. SISK

BY

ATTORNEY

United States Patent Office

3,180,274
Patented Apr. 27, 1965

3,180,274

SILENT VARIABLE DELIVERY HYDRAULIC PUMP

Francis J. Sisk, Pittsburgh, Pa. (Military Assistance Group (MAG), Viet Nam, A.P.O. Box 143, San Francisco, Calif.)

Filed June 4, 1962, Ser. No. 200,005
12 Claims. (Cl. 103—162)
(Granted under Title 35, U.S. Code (1952), sec. 266)

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

This invention relates to hydraulic power transmission systems, and more particularly it relates to those systems which will function as pumps when driven mechanically and will function as fluid motors when supplied with fluid under pressure (overhauling). Systems of this type are sometimes referred to as servo pumps. The particular servo pump to which this invention relates is the type having a rotatable barrel containing a plurality of cylinders and a plurality of parallel pistons in the cylinders, which pistons move axially along the axis of rotation of the barrel as the machine is operated although it is to be understood that it is also applicable to many other types of reciprocating pumps.

In hydraulic transmission machines of the type described above, it has been found that considerable noise results during machine operation, especially when such machines are operated under excessive conditions of load or speed. Such noise is a result of the shock which occurs when a cylinder having a certain pressure therein is brought into or out of communication with a port in a valve plate having a different pressure therein. In certain environments, such as ships and submarines, hydraulic machines of the type described above have proved to be very useful; however, the excessive noise produced by their operation has presented a serious problem. Attempts have been made to reduce or suppress such noise by acoustic treatment, flexible mountings, and the like, but such attempts have not proved entirely satisfactory. The result is that when quiet operation is a critical factor, as it is on almost all submarines, such machines cannot be used, and, instead, designers have been forced to employ less efficient, heavier, less flexible and more costly fluid transmission devices, such as constant displacement pumps.

An object of this invention is to provide a rotary barrel, parallel piston machine, of the type described above, wherein the pressure difference between the cylinders and valve ports is practically eliminated, thereby reducing noise generation caused by operation of the machine.

Another object of this invention is to provide a noise-free hydraulic power transmission system which can be used for bi-directional operation.

A further object of this invention is to provide a hydraulic power transmission machine with a high overall efficiency, which machine is simple in construction and low in cost of manufacture.

Further objects and advantages will become apparent from the ensuing descriptive matter.

This invention broadly is comprised of a rotatable barrel assembly adapted to draw fluid in through passage-connecting means preferably in the form of a valve plate at one pressure and expel it through the valve plate at another pressure. The rotatable barrel assembly is comprised of a barrel body having a plurality of parallel cylinders therein, each cylinder having a main passage and two check valve equipped passages communicating with the cylinder. A plurality of parallel pistons are mounted within the cylinders, the pistons being driven reciprocably by a swash plate assembly. The valve plate is provided with a suction port and a main discharge port which communicate with the cylinders through the main passages. The valve plate also is provided with auxiliary suction and discharge ports which communicate with the cylinders through the check valve equipped passages and which also communicate with the main ports of the valve plate directly or through a shuttle valve assembly. The check valve controlled passages, the auxiliary ports, and the shuttle valve assembly all cooperate so that fluid trapped in each cylinder at one main port closure is either expanded or compressed, as necessary, during its transit of the auxiliary ports so that its pressure will be smoothly changed to the pressure of the other main port. Thus, when the fluid is admitted to or discharged from the cylinder, there is no pressure difference and, therefore, no noise caused by shock.

The invention will be more completely understood from the following detailed description and claims, read in conjunction with the annexed drawings, in which:

FIG. 1 is a partial longitudinal sectional view diagrammatically showing an embodiment of a servo pump in accordance with the present invention;

FIG. 2 is a transverse sectional view taken on a plane indicated by the line 2—2 of FIG. 1;

FIG. 3 is a transverse sectional view taken on line 3—3 of FIG. 1, showing the shuttle valve in the pumping position;

FIG. 3A is a partial sectional-view showing the shuttle valve of FIG. 3 in reversed pumping position;

FIG. 4 is a transverse sectional view of a modified form of the invention taken on a plane indicated by line 3—3 of FIG. 1, showing the shuttle valve in pumping position;

FIG. 4A is a partial sectional view showing the shuttle valve of FIG. 4 in overhauling position; and

FIG. 5 is a transverse sectional view of a flow reversing valve assembly which can be used with the modified form of the invention shown in FIG. 4.

Referring now to FIG. 1, a hydraulic power transmission machine or servo pump in accordance with the present invention is shown in which a casing **10** is closed at one end by a head **12** and at the other end by an annular cover **14** which is attached to the casing by bolts **16**. The head **12** is provided with an inlet passage **18** and an outlet passage **20**, which passages are arranged to communicate with passage-connecting means in the form of a stationary circular valve plate **22**. A cylindrical shaft **24** is journaled in anti-friction bearings **26** and extends through the valve plate **22** into the interior of the casing **10**. A cylindrical barrel assembly **28** is fixedly mounted on the shaft **24** and adapted to rotate therewith. The barrel assembly is spaced from the interior of the casing **10** by means of roller bearings **30** which allow the barrel assembly to rotate within the casing.

The cylindrical barrel assembly **28** comprises a cylindrical barrel body having a plurality of circumferentially spaced cylinders **34** formed therein, said cylinders being equally radially spaced from but extending parallel to the shaft **24**. As can best be seen in FIG. 2, each cylinder has a main passage **36** and two check valve equipped passages, **38** and **40**. The check valves are arranged so that the passages **38** only allow flow out of the cylinders **34** and the passages **40** allow flow only into the cylinders. The functions and purposes of passages **36**, **38**, and **40** will be discussed more fully later, but at this point it can be said that these passages are adapted to effect a communication, through the valve plate **22**, with the inlet passage **18** and the outlet passage **20**.

A plurality of pistons **42** are located within the cylinders **34**, there being one piston for each cylinder. Each of the pistons has a ball type head **44**; and the pistons are reciprocable in the cylinders, the reciprocation being obtained through a cam means or swash plate means **45** as the shaft 24 rotates. The swash plate means comprises a plurality of slippers or shoes 46, one for each ball head 44, comprises a swash plate 48, and comprises a control shaft 50.

The ball head of each piston is journaled in its associated shoe, the shoe riding freely along the face of the swash plate 48 as the barrel 32 rotates. Since the swash plate is disposed angularly or inclined to the axes of the pistons and cylinders, the swash plate actually forms a cam surface that causes the pistons 42 to reciprocate as they are being revolved by barrel 32.

The inclination of swash plate 48 to the shaft 24 and to the pistons may be varied by changing the inclination of the shaft 50. When the plane of the swash plate is perpendicular to the axes of the pistons, which is vertical in the embodiment shown in FIG. 1, the stroke of the pistons is zero. As the swash plate is inclined, the stroke of the pistons is increased. At maximum inclination of the swash plate, forty-five degrees displaced from the vertical, the stroke of the pistons is at its maximum.

An insert 52 is mounted in the end of shaft 24 and locked to the barrel body 32, thereby locking the shaft and barrel body together so that they rotate as a unit. A plunger 54 is mounted in the insert 52 and extends to the center of the swash plate, with one end of the plunger being spaced away from the bottom of the insert by a compression spring 56 and the other end of the plunger pressing against a spherical ball 58. The ball 58 freely seats in a seat on the swash plate 48 in such a manner that the spherical ball 58 acts as a bearing against which the swash plate bears, so that the swash plate can be rotated through a range of positions on opposite sides of the shaft 24 as indicated by the arrows 59 in FIG. 1. The swash plate can be moved to any position within 45 degrees on either side of the vertical position, thereby allowing reversible or bi-directional flow. For example, FIG. 1 shows the machine operating as a pump, with lower pressure fluid being introduced through inlet 18, and as the cylinder assembly 28 is rotated by the shaft 24, the pistons compress the fluid, and the fluid is discharged under high pressure when the associated cylinder communicates with the outlet 20.

The machine of FIG. 1 can also pump in the opposite direction as that recited above. That is, lower pressure fluid could be introduced through the outlet 20, and as the cylinder assembly is rotated by the shaft 24, the pistons would compress the fluid and discharge it under high pressure when the associated cylinder is in communication with the inlet 18. To accomplish this, the swash plate 48 would have to be moved by the control shaft 50 to a position where it was angularly displaced on the other side of the vertical position. An upwardly directed centerline for the control shaft 50 is shown in FIG. 1 at the upper arrow 59, which would correspond to the position of the control shaft under such reversed conditions.

If it were desired to use the machine only for unidirectional flow, that is only for pumping or only for overhauling, the swash plate could be mounted to rotate about an axis of one of the pistons, rather than about the axis of the centerline of the shaft. An arrangement such as this is shown in United States Patent No. 1,506,892. Such an arrangement has the advantages of allowing greater variations in the length of stroke of the pistons, and also of keeping to a minimum the volume in each cylinder at zero stroke, thus keeping to a minimum the amount of energy that can cause noise; however, such operation is achieved through the sacrifice of the feature of reversible or bi-directional flow. Such operation is discussed later in connection with the modification of FIG. 4.

Referring now to FIG. 3, a valve plate 22 is shown, which plate is adapted for use in a machine having the bi-directional or reversible flow type of swash plate mounting. The valve plate is provided with a main port

60 and a main port 62, which ports are radially arranged to align with the main passages 36 of the cylinders. Auxiliary suction ports 64 and 66 are provided, which ports are radially arranged to align with the inlet check valve equipped passages 40 of the cylinders. Auxiliary discharge ports 68 and 70 are also provided which ports are radially arranged to align with the outlet check valve equipped passages 38 of the cylinders. The auxiliary suction ports 64 and 66 are directly connected to each other by a flow passage 72. The auxiliary discharge ports 68 and 70 are directly connected to each other by a similar flow passage 74. The auxiliary ports are connected with the main ports through a shuttle valve means or assembly 76.

The shuttle valve assembly 76 can be of any standard construction consistent with the functions which it must perform. The particular shuttle valve assembly illustrated in FIG. 3 comprises a valve body 78 and a three piston slide valve member 80 which reciprocates within the valve body.

A conduit 82 connects the main suction port 60 to the shuttle valve assembly. The conduit 82 has a branch line 84 extending into one end of the valve body 78 and also has branch lines 86 and 88 extending into spaced ports at the top of said valve body. A conduit 90 connects the main port 62 to the shuttle valve assembly. The conduit 90 has a branch line 92 extending into the other end of the valve body 78 and also has a branch line 94 extending into a port at the top of said valve body at a point substantially intermediate between the ports for the branch lines 86 and 88.

A conduit 96 connects the auxiliary suction ports 64 and 66 to a port in the lower portion of the valve body 78; and a conduit 98 connects the auxiliary discharge ports 68 and 70 to another port in the lower portion of said valve body.

It can thus be seen each port on the valve plate is connected to the shuttle valve assembly by means of a conduit and, according to the position of the valve member 80, the conduits, and thus their ports, can be interconnected with one another.

Operation (FIG. 3)

Assume that the device is pumping, with the parts in the position illustrated in FIG. 3, and the swash plate 48 in the position shown in FIG. 1. Fluid at low pressure is supplied to the inlet passage 18 and is then compressed to a higher pressure and discharged through the outlet passage 20. Since the inlet pressure (which is present in main suction port 60) is less than the discharge pressure (which is present in main discharge port 62), the shuttle valve slide member 80 assumes the position indicated.

When operating under such conditions, as the barrel 32 is rotated, a cylinder 34 is aligned with the main suction port 60 and low pressure fluid is drawn into said cylinder through the main passage 36 by a suction force caused by the piston 42 in that cylinder being withdrawn. As the barrel continues to rotate, the check valve equipped passages 38 and 40 will move into communication with the auxiliary ports 68 and 64 respectively. Since the auxiliary port 64 is in direct connection with the main suction port 60 (through the conduit 96, the branch line 86 and the conduit 82), low pressure fluid is supplied to said auxiliary port 64 and is drawn into the cylinder through the inlet check valve equipped passage 40. Even after the cylinder has rotated out of communication with the main suction port 60, additional low pressure fluid will continue to enter the cylinder through the passage 40, until the cylinder finally reaches top dead center (TDC). At this point, the piston 42 in the cylinder has been completely withdrawn and is at the end of its stroke.

As the barrel continues to rotate, the piston 42 starts to move back into the cylinder, thus compressing the fluid contained therein. After a short period the fluid will have reached the discharge pressure and it will thereafter be discharged through the auxiliary discharge port via passage 38 and then to the main discharge port 62 via passages 98, 94 and 90. When the main passage 36 registers with main discharge port 62, the fluid in the cylinder is at discharge pressure, and thus no shock noise occurs. As the piston 42 continues to move into the cylinder, it exhausts the fluid through the main passage 36 and into the main discharge port 62.

The remaining operation becomes obvious in view of the above description. When the cylinder reaches bottom dead center (BDC), the piston 42 is all the way into the cylinder and substantially all the fluid has been exhausted therefrom. As the cylinder continues to rotate, the piston starts to withdraw, thus first reducing the pressure of the fluid (passage 38 being closed), then drawing low pressure fluid from auxiliary port 66 into the cylinder through the inlet check valve equipped passage 40. When the cylinder is finally brought back into communication with the main suction port 60, thereby completing a 360 degree transit, the fluid in the cylinder is at suction pressure, and thus no shock wave occurs.

When the operation is reversed so the machine is pumping in the reverse direction, the outlet 20 becomes the inlet and the inlet 18 becomes the outlet. Thus, low pressure fluid enters at the main port 62 and leaves at the main port 60 as high pressure fluid. This change in pressures causes the shuttle valve member 80 to shift to the right, as shown in FIG. 3A. The only change which must be made to allow the machine to operate under such conditions is to change the swash plate 48 from its FIG. 1 position through the arc indicated by the arrow 59. When the swash plate has been thus shifted, the machine will now operate in the same manner as that described above.

The check-valve controlled passages 38 and 40 preferably are made smaller than the main passages 36, since the flow occurs through them in the vicinity of the top and bottom dead centers and thus is at the low flow rate. The area of the check valve controlled passages may thus be made smaller, thereby conserving maximum area for the main ports.

Referring now to FIG. 4, a modified form of the invention is shown, wherein a valve plate 110 is shown having a main suction port 112, a main discharge port 114, auxiliary suction ports 116 and 118, and auxiliary discharge ports 120 and 122. The main valve plate ports are radially arranged to align with the main passages 36 of the cylinders 34, while the auxiliary suction ports are radially arranged to align with the inlet check valve equipped passages 40, and the auxiliary discharge ports are radially arranged to align with the outlet check valve equipped ports 38. One auxiliary suction port 116 is directly connected to the main suction port 112 by means of a flow passage 124. Similarly, one auxiliary discharge passage 122 is directly connected to the main discharge port 114 by means of a flow passage 126. The other auxiliary suction port 118 and the other auxiliary discharge port 120 are connected with their respective main ports through a shuttle valve means or assembly 128 having a slide piston member 129 therein. The slide piston member 129 is comprised of three interconnected spaced pistons 130, 132, and 134 which are arranged as shown in FIG. 4. A valve stem 136 interconnects the pistons. A duct 138 extends through the piston 130 and the valve stem 136 to communicate with the space between pistons 130 and 132. Similarly, a duct 140 extends through the piston 134 and the valve stem 136 to communicate with the space between pistons 132 and 134.

The shuttle valve assembly 128 is connected with the valve plate 110 by means of five conduits. Conduits 142 and 144 connect the shuttle valve assembly to the main suction and discharge ports, respectively. Conduit 146 connects into conduit 148 and both conduits connect the shuttle valve assembly to the auxiliary suction port 118. Conduit 150 connects the shuttle valve assembly to the auxiliary discharge port 120.

Operation (FIG. 4)

When the device is operating as a pump, as shown in FIG. 4, low pressure exists at port 112 and high pressure exists at port 114 thus causing the shuttle valve member 129 to shift to the left. The low pressure fluid is introduced from the inlet 18 into the main suction port 112. A cylinder 34 rotating past this port would have this fluid drawn thereinto through the main passage 36, as the piston 42 in that cylinder was withdrawing. Even after the cylinder rotated beyond the main suction port 112, low pressure fluid will continue to be drawn into the cylinder through the check valve equipped inlet passage 40. This low pressure fluid comes from the auxiliary port 118 and is supplied thereto from the main suction port 112 by means of the conduit 142, the duct 138 and the conduit 148. When the cylinder rotates to top dead center (TDC), the piston 42 within that cylinder is completely withdrawn and the cylinder is full of low pressure fluid.

As the cylinder rotates beyond top dead center, the piston starts to move back inward thus tending to compress the fluid. When the fluid is compressed sufficiently to bring it up to discharge pressure, it starts to discharge from the cylinder through the outlet check valve equipped passage 38 and into the auxiliary discharge port 122 from which it flows through the duct 126 and into the main discharge port 114. When the cylinder rotates into communication with the main discharge port 114, the fluid in the cylinder is at the discharge pressure, thus no shock noise occurs.

Even after the cylinder 34 has rotated beyond the main discharge port 114, high pressure fluid will continue to be discharged from the cylinder as the piston continues to move inward. This fluid is discharged through the outlet check valve equipped passage 38 and flows into the auxiliary discharge port 120 and through the conduit 150, the duct 140 and the conduit 144 and back to the main discharge port 114. By the time the cylinder reaches bottom dead center (BDC), the piston will have moved all the way into the cylinder and substantially all of the fluid in the cylinder will have been discharged.

As the cylinder rotates beyond bottom dead center, the piston starts to withdraw therefrom reducing the cylinder pressure, and when the inlet pressure is reached fluid of low pressure is drawn from the main suction port 112, through the flow passage 124, through the auxiliary port 116 and into the cylinder through the inlet check valve equipped passage 40. When the cylinder subsequently rotates into communication with the main suction port 112, the fluid in the cylinder is at the inlet pressure, thus no shock noise occurs.

Operation (FIG. 4A)

When the device is operating as a fluid motor, or overhauling, high pressure exists at port 112 and low pressure exists at port 114 thus causing the shuttle valve to shift to the right as shown in FIG. 4A. The high pressure fluid is introduced from the inlet 18 into the main suction port 112. A cylinder 34 rotating past this port would have this high pressure fluid drawn thereinto through the main passage 36, as the piston 42 in that cylinder was withdrawing.

After the cylinder rotates beyond the main suction port 112, no further high pressure fluid can enter the cylinder, since the auxiliary suction port 118 is not connected to the high pressure source at main port 112. As the piston withdraws in the cylinder, the fluid pressure is decreased to bring it down to low pressure. If the expansion should take the fluid pressure below that pressure existing at the main discharge port 114, low pressure fluid from the main port 114 will be transferred to said cylinder by means of the conduit 144, the duct 140, the conduit 146, the conduit 148 to the auxiliary port 118 and through the inlet check valve equipped passage 40 into the cylinder.

When the cylinder reaches top dead center (TDC) the piston is completely withdrawn and the cylinder is full of low pressure fluid. As the cylinder rotates past top dead center, the piston starts to move back into the cylinder, thus forcing the fluid through the outlet check valve equipped passage 38, through the auxiliary port 122 and the flow passage 126 and into the main discharge port 114. When the cylinder finally rotates into communication with the main discharge port 114, the fluid in the cylinder is at the low discharge pressure, thus no shock noise occurs. As the piston moves inward into the cylinder, the fluid is forced out through the main passage 36 into the main discharge port 114, from whence it flows to the outlet passage 20.

When the cylinder rotates beyond the main discharge port, no further outflow of fluid occurs until the fluid is compressed to a pressure higher than the inlet or high pressure. At this point, the high pressure fluid flows out through the outlet check valve equipped passage 38 to the auxiliary port 120 and from there through the conduit 150, the duct 138 and the conduit 142 to the main suction port 112. When the cylinder reaches bottom dead center (BDC), the piston is all the way into the cylinder and substantially all of the fluid has been discharged.

When the cylinder rotates beyond bottom dead center, the piston starts to withdraw and high pressure fluid starts to enter the cylinder through the inlet check valve equipped passage 40. This high pressure fluid flows from the main suction port 112, through the flow passage 124 into the auxiliary port 116, and from there into the passage 40. When the cylinder is rotated further so it comes back into communication with the main suction port 112, thereby completing a 360 degree transit, the fluid in the cylinder is exactly at high or inlet pressure, thus no shock noise occurs.

The essential difference between the embodiment of FIG. 3 and that of FIG. 4 is in the range of operations which each can perform. The valve plate of FIG. 3 can be used when the device is operated to pump when fluid is flowing in one direction or the opposite direction. It can pump but not overhaul for both directions of fluid flow, free of shock noise. The valve plate of FIG. 4 can be used for operating the device either as a fluid motor (overhauling) or as a pump. However, it is limited to monodirectional flow. Therefore, in order to achieve bi-directionality using the valve plate of FIG. 4, it is necessary to use a flow reversing valve assembly. Such a valve assembly is shown in FIG. 5.

The flow reversing valve assembly shown in FIG. 5 comprises a shuttle valve means 152 and a cam means 154. The valve means 152 includes a valve body 156 and a three piston valve member 158 slidable within said valve body. A conduit 160 connects the valve means to the inlet passage 18 and a conduit 162 connects the valve means to the outlet passage 20. A pair of conduits 164 and 166 connect the valve means with the load. Conduit 166 has a branch line 168 connected therewith so there are actually two connections to the valve body 156. The conduits 160, 162 and 164 have enlarged orifices in the valve body 156 so that when the valve member 158 is in its neutral or center position (a condition, as will be presently described, when the swash plate is vertical), cross-flow can occur between the inlet 18 and the outlet 20.

A control rod 170 extends between the valve member 158 and the cam means 154 for the purpose of controlling movement of said valve member. The cam means 154 includes a lower portion for controlling movement of the valve member 158 and an upper portion for controlling movement of the swash plate 48. The lower portion has a higher surface 172 and a lower surface 174.

FIG. 5 shows the control rod 170 bearing upon the higher surface, thus causing the valve member 158 to be moved to the left position. In this position, fluid flows into the servo pump through the conduits 166 and 169 and out of the servo pump through the conduits 162 and 164. If the cam means were shifted so the control rod 170 bore upon the lower surface 174, flow in the system would be reversed, since the valve member 158 would move to the right thus causing fluid into the servo pump through the conduits 164 and 160 and out of the servo pump through the conduits 162 and 166 (by means of the branch line 168).

The upper portion of the cam means 154 consists of two sloped planar surfaces 176 and 178 which meet at a point 180. A control rod 182 rides along the surfaces 176 and 178 and has its other end linked to the control shaft 50 of the swash plate 48. Thus, it can be seen that as the cam means 154 moves, the inclination of the swash plate is changed from full stroke inclination (at the highest portion of surfaces 176 and 178) to no inclination (at point 180). When the control rod 182 is at point 180, the control rod 170 is midway between surfaces 172 and 174, thus causing the valve member 158 to assume the neutral position previously referred to.

It can thus be seen that the present invention provides a silent fluid transfer device which can be used for pumping fluid from low pressure to high pressure in either direction (i.e. either left to right or right to left) and which can also be used for overhauling or motoring fluid from high pressure to low pressure in either direction.

It will be understood that various changes in the details, materials, steps and arrangements of parts, which have been herein described and illustrated in order to explain the nature of the invention, may be made by those skilled in the art within the principle and scope of the invention as expressed in the appended claims.

What is claimed is:

1. In a hydraulic power transmission machine:

(*a*) a valve means including two main ports, two auxiliary suction ports and two auxiliary discharge ports;

(*b*) said auxiliary suction ports being directly connected to each other and said auxiliary discharge ports being directly connected to each other;

(*c*) said auxiliary suction and discharge ports being selectively connectable to either main port; and

(*d*) means responsive to pressures in said main ports comprising pressure operated valve means operable to effect such selective connection.

2. A hydraulic power transmission system of the type which is operable as a fluid motor to convert high pressure fluid to low pressure fluid and which is operable as a pump to convert low pressure fluid to high pressure fluid, and which can be operated under reversible conditions of flow, said system comprising:

(*a*) a casing having an annular cover at one end thereof and a head at the other end thereof;

(*b*) said head having an inlet and an outlet for said fluid and a central cavity portion in which anti-friction bearings are mounted;

(*c*) a valve plate fixed within said casing adjacent said head, said valve plate having a central aperture therethrough;

(*d*) a shaft positioned within said bearings and extending into said casing through said valve plate aperture;

(*e*) a barrel mounted on said shaft adjacent said valve plate, said barrel being spaced away from the interior of said casing by roller bearings;

(*f*) a plurality of cylinders within said barrel parallel to the axis of said shaft, each of said cylinders terminating in three passages one of which is open, one of which is controlled by a check valve which only allows flow into the cylinder and one of which is controlled by a check valve which only allows flow out of the cylinder;

(*g*) said valve plate having a main suction port, a main discharge port, two auxiliary suction ports and two auxiliary discharge ports, said ports being arranged so that said main ports communicate only with said open passages, said auxiliary suction ports communicate only with said inlet check valve controlled passages, and said auxiliary discharge ports communicate only with outlet check valve controlled passages;

(*h*) a plurality of pistons mounted, one in each cylinder, each of said pistons having a ball type head adapted to fit into a slipper;

(*i*) a swash plate movably mounted in said annular cover and having a flat surface upon which slippers can freely ride;

(*j*) said swash plate mounting including a spherical bearing mounted between said swash plate and a plunger which extends from a fitting in the end of said shaft; and

(*k*) a control shaft fixed to said swash plate for varying the angular position thereof with respect to the axis of said pistons and shaft;

(*l*) whereby when fluid is introduced through said inlet it flows through said valve plate and into said cylinders which thereupon rotate around the axis of said shaft to cause said pistons to reciprocate within said cylinders thus changing the pressure of said fluid in said cylinders, which fluid is finally discharged through said valve plate and said outlet.

3. A system as described in claim 2 wherein said auxiliary suction and discharge ports are directly connected to each other respectively, and are connected to said main ports by means of a shuttle valve, the position of which is determined by the fluid pressure in said system, whereupon the pressure of fluid in transit in a cylinder from one main port to the other can be controlled by means of allowing some fluid to enter or leave said cylinder through said auxiliary ports and said check valve controlled passages.

4. A system as described in claim 2 wherein one auxiliary suction port is directly connected to said main suction port, one auxiliary discharge port is directly connected to said main discharge port, and the other auxiliary suction and discharge ports are connected to said main ports by means of a shuttle valve, the position of which is determined by the fluid pressure in said system, whereupon the pressure of fluid in transit in a cylinder from one main port to the other can be controlled by means of allowing some fluid to enter or leave said cylinder through said auxiliary ports and said check valve controlled passages.

5. A servo pump for transferring incoming fluid at a first pressure to outgoing fluid at a second pressure, the pressure change occurring during transference, said pump comprising:

(*a*) a hollow casing member having a cover with an annular opening at one end of said casing and a head portion having a fluid inlet and a fluid outlet, said head portion being at the other end of said casing;

(*b*) a valve plate nonrotatably mounted within said casing adjacent said head portion, said valve plate having a plurality of ports therein, said ports being adapted to communicate with said inlet and said outlet;

(*c*) a barrel assembly rotatably mounted within said casing;

(*d*) a rotatable shaft axially fixed to said barrel;

(*e*) said barrel assembly including a plurality of cylinders extending from the annular opening in said cover toward said valve plate, said cylinders terminating before said valve plate but communicating therewith by means of three passages for each cylinder, said passages consisting of a main passage, a valve controlled passage allowing only outflow from the cylinder, and a valve controlled passage allowing only inflow into the cylinder;

(*f*) said barrel assembly further including a plurality of pistons, one of said pistons being mounted in each of said cylinders and being adapted to reciprocate therein;

(*g*) means for reciprocating said pistons within said cylinders to cause fluid to be drawn into and discharged from cylinders, the reciprocation of said pistons effecting a change in the pressure of the fluid contained within said cylinders;

(*h*) said valve plate ports including a pair of main ports and a plurality of auxiliary ports, said main ports communicating with said inlet and outlet on one side thereof and communicating with said cylinder main passages on the other side thereof, said auxiliary ports communicating selectively with said main ports and said auxiliary ports also communicating with said cylinder inflow and outflow passages; and

(*i*) means for effecting the communication of said auxiliary ports with said main ports;

(*j*) whereby fluid at a first pressure enters the pump through said inlet and flows through one of said main ports and said main passages into said cylinders, said shaft rotates said barrel assembly thereby reciprocating the pistons within said cylinders to change the pressure of said fluid, and while said reciprocation occurs some additional fluid enters said cylinders through said auxiliary ports and inflow passages and some fluid in the cylinders leaves said cylinders through said outflow passages and auxiliary ports, all to the end that when said cylinders finally rotate into communication with the other of said main ports and said outlet, the pressure of the fluid within said cylinders is equalized with the pressure of said outlet, with the result that no shock noise occurs as said fluid is discharged.

6. A servo pump as described in claim 5 wherein said means for reciprocating said pistons is a swash plate pivotally mounted within the annular opening in said cover and adjustable to form a cam surface upon which said pistons ride as said barrel assembly is rotated.

7. A servo pump as described in claim 5 wherein the means for effecting communication between said auxiliary ports and said main ports is a shuttle valve, the position of which is determined by the pressure differential between said inlet and said outlet.

8. A servo pump as described in claim 7 wherein said auxiliary ports include two auxiliary suction ports radially located to align with said cylinder inflow passages and two auxiliary discharge ports radially located to align with said cylinder outflow passages.

9. A servo pump as described in claim 8 wherein said auxiliary suction ports are connected directly to one another and are also connected to said shuttle valve, and wherein said auxiliary discharge ports are connected directly to one another and are also connected to said shuttle valve, whereby, depending on the position of said shuttle valve, both auxiliary suction ports are connected to the main suction port and both auxiliary discharge ports are connected to said main discharge port, or vice versa.

10. A servo pump as described in claim 8 wherein one of said auxiliary suction ports is connected directly to said main suction port and one of said auxiliary discharge ports is connected directly to said main discharge port, the other of said auxiliary suction ports is connected to said shuttle valve, and the other of said auxiliary discharge ports is connected to said shuttle valve, whereby, depending upon the position of said shuttle valve, either both of said auxiliary suction ports are connected to said main suction port and both of said auxiliary discharge ports are connected to said main discharge port, or one of

said auxiliary suction ports and one of said auxiliary discharge ports is connected to each main port.

11. In a hydraulic power transmission machine:

means defining a plurality of cylinders each having a piston reciprocable therein;

means for reciprocating said pistons;

valve plate means adapted to control fluid flow into and out of said cylinders upon reciprocation of said pistons;

said valve plate means including two main ports, two auxiliary suction ports, and two auxiliary discharge ports;

said auxiliary suction ports being directly connected to each other for fluid flow therebetween, and said auxiliary discharge ports being directly connected to each other for fluid flow therebetween;

said auxiliary suction and discharge ports being selectively connectible to either of said main ports; and

means responsive to pressures in said main ports comprising pressure operated valve means operable to effect such selective connection.

12. In a hydraulic power transmission machine:

means defining a plurality of cylinders each having a piston reciprocable therein;

means for reciprocating said pistons;

valve plate means adapted to control fluid flow into and out of said cylinders upon reciprocation of said pistons;

said valve plate means including two main ports, two auxiliary suction ports, and two auxiliary discharge ports;

said auxiliary suction ports being directly connected to each other for fluid flow therebetween, and said auxiliary discharge ports being directly connected to each other for fluid flow therebetween;

said auxiliary suction and discharge ports being selectively connectible to either of said main ports;

means responsive to pressures in said main ports comprising pressure operated valve means operable to effect such selective connection;

said means defining said cylinders further defining three passages communicating with each of said cylinders;

a first of said three passages being registerable only with said main ports upon relative rotation between said cylinders and said valve plate means;

a second of said three passages being registerable only with said auxiliary suction ports upon said relative rotation; and

a third of said three passages being registerable only with said auxiliary discharge ports upon said relative rotation.

References Cited by the Examiner

UNITED STATES PATENTS

2,288,768	7/42	Zimmermann	103—162
2,553,655	5/51	Herman et al.	103—162
2,963,983	12/60	Wiggermann	103—162
2,976,863	3/61	Duer et al.	121—62

FOREIGN PATENTS

1,020,525	12/57	Germany.	

LAURENCE V. EFNER, *Primary Examiner.*