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3,266,436

MULTIPLE PISTON TYPE PUMP OR MOTOR

Filed Sept. 1, 1964

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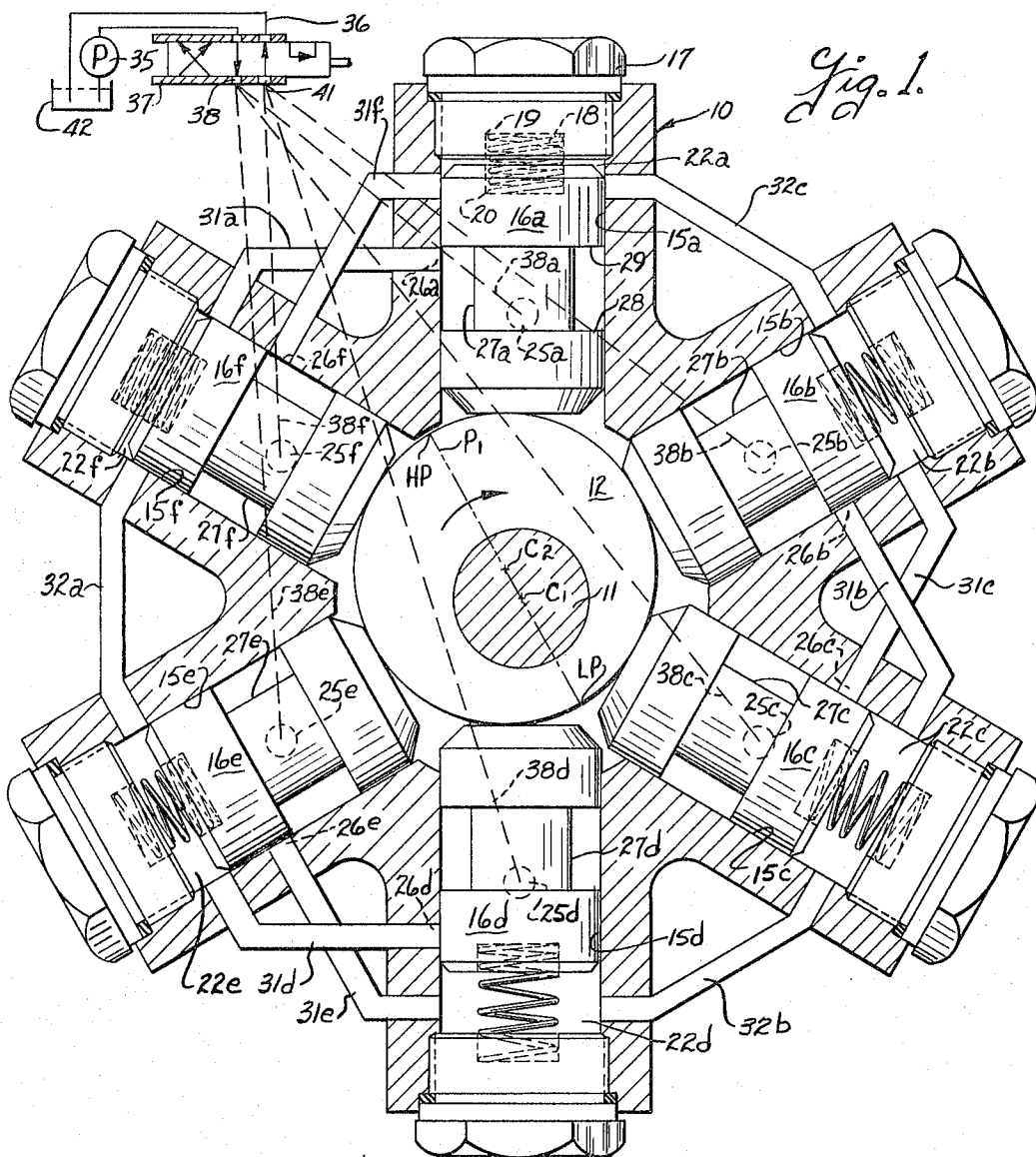


Fig. 1.

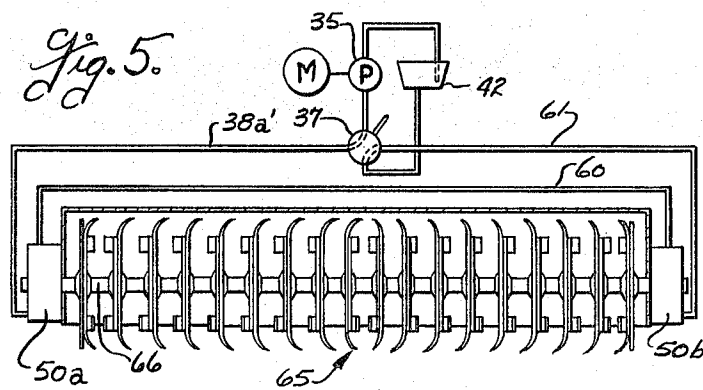


Fig. 5.

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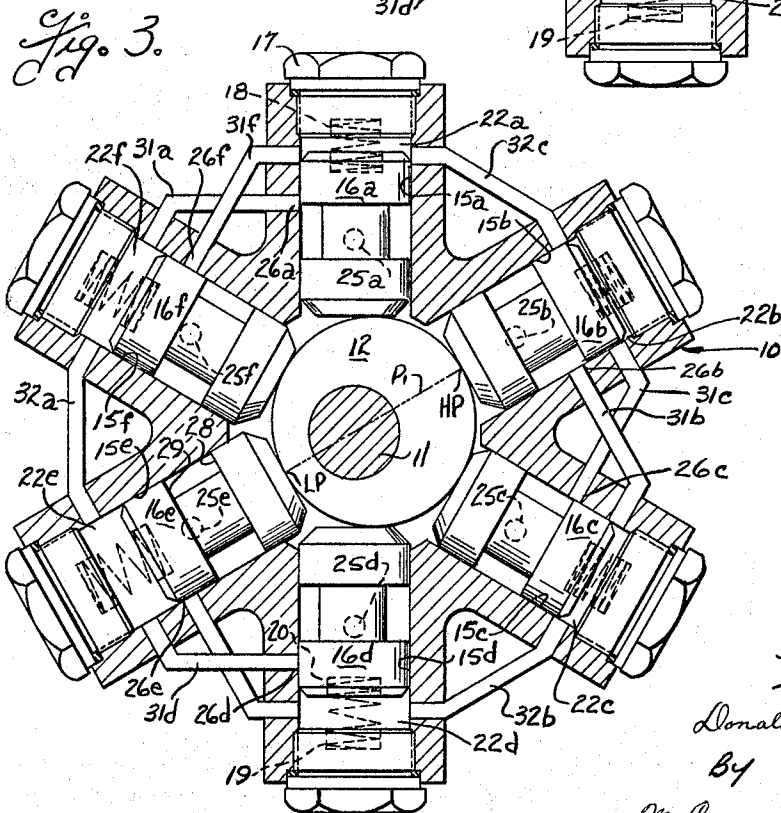
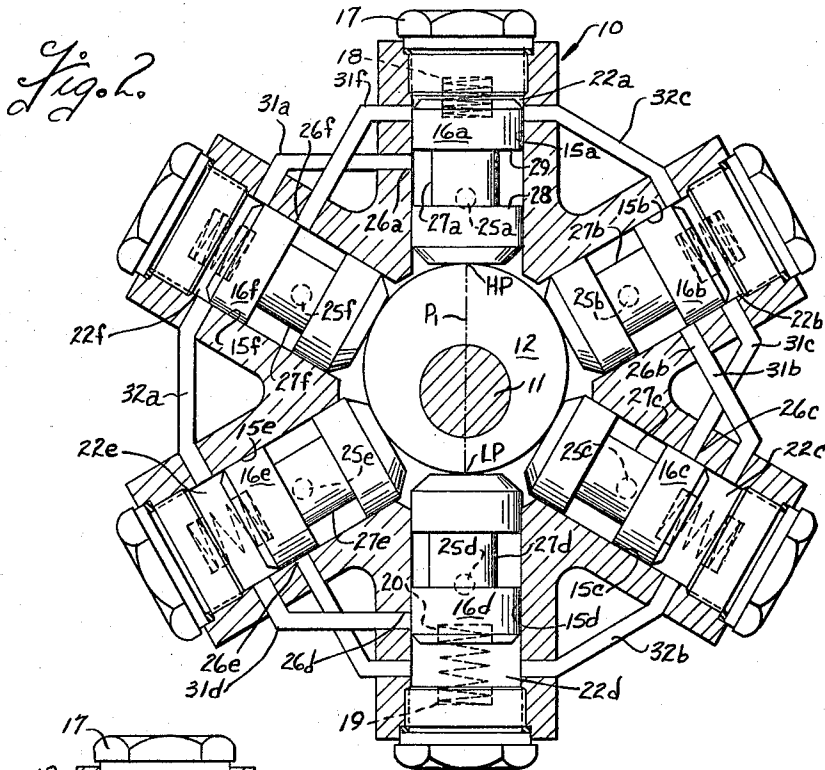
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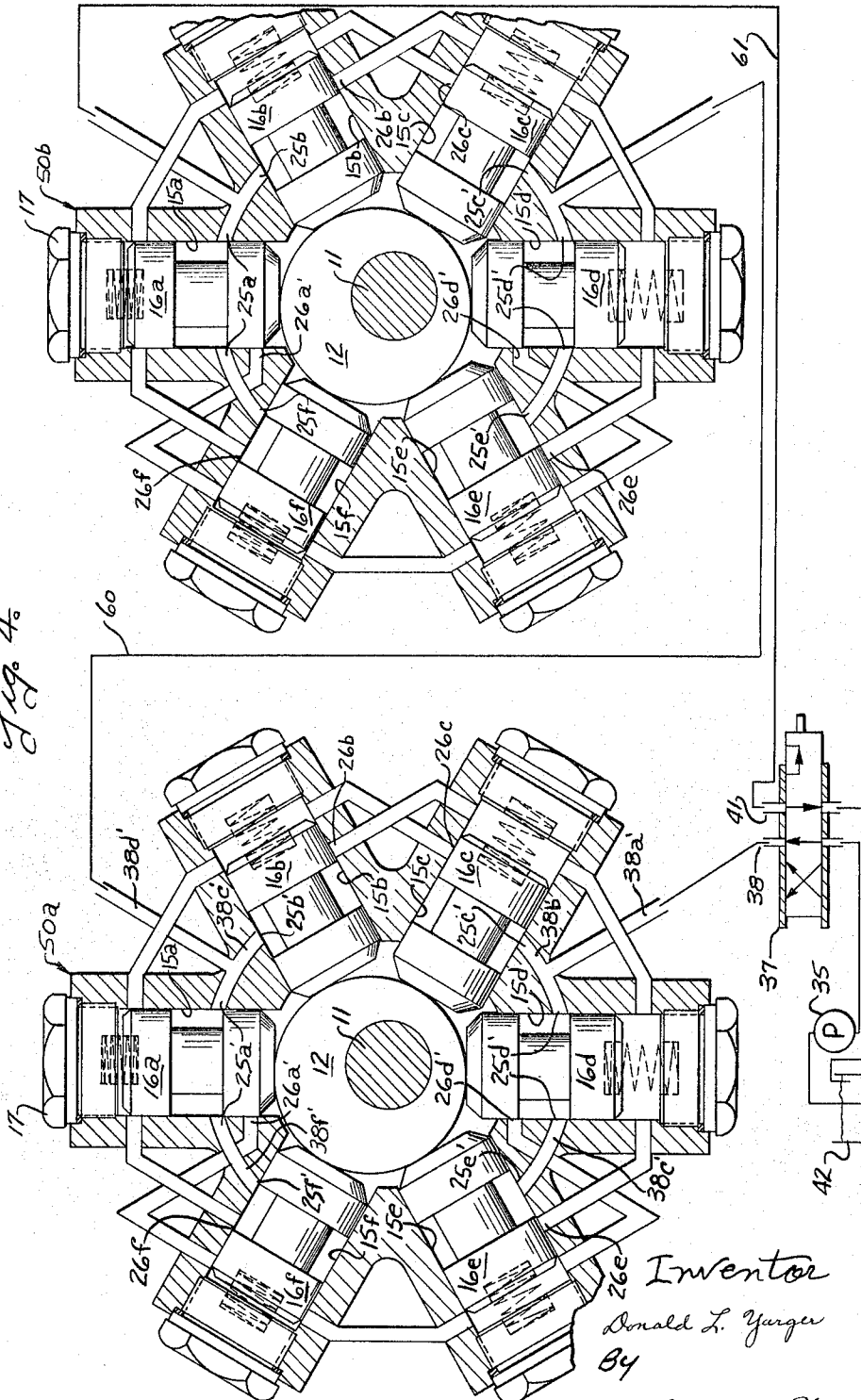
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Fig. 4



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MULTIPLE PISTON TYPE PUMP OR MOTOR

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Filed Sept. 1, 1964, Ser. No. 393,690

16 Claims. (Cl. 103-174)

This invention relates to fluid pumps or motors and particularly to a multiple piston type pump or motor.

An important object of this invention is to provide a multiple piston type pump or motor having an improved valving arrangement for valving the flows of fluid to and from the cylinders in sequential phased relation in which the valves are so arranged as to minimize leakage between the inlet and return lines and to avoid flow reversal through the valves to achieve more positive and efficient operation.

Another object of this invention is to provide a multiple piston type pump or motor having inlet valve means on certain of the pistons for valving the flows of fluid to the several cylinders, and outlet valve means on others of the pistons for valving the flows of fluid from the several cylinders, which inlet and outlet valve means has an improved port arrangement that simplifies timing of the valving functions of the pistons and facilitates economical manufacture of the pump or motor.

Yet another object of this invention is to provide a multiple piston type pump or motor in which at least several pistons, operated out of phase with each other, are under pressure in all positions of the shaft to provide smooth operation.

A further object of this invention is to provide a multiple piston type fluid pump or motor which avoids hydraulic locking of the pistons in the cylinders while the cylinders are undergoing valving.

Still another object of this invention is to provide a multiple piston type pump or motor in which pairs of cylinders having pistons operated out of phase with each other are hydraulically interconnected and the valving is so arranged that when the valves operate to block flow to the interconnected pairs of cylinders, incident to transition between pressure and exhaust in the cylinders, the pistons in the interconnected pairs of cylinders are moving in relatively opposite directions so that the fluid displaced from one of the blocked cylinders will be transferred into the other of the blocked cylinders to thereby avoid hydraulic lock.

A further object of this invention is to provide a novel arrangement for operating pairs of piston type pumps or motors in synchronism.

These, together with other objects and advantages of this invention will be more readily appreciated as the invention becomes better understood by reference to the following detailed description when taken in connection with the accompanying drawings wherein:

FIGS. 1, 2 and 3 are transverse sectional views through a fluid pump or motor with the valving passages shown diagrammatically and illustrating the parts in different successive rotative positions of the shaft;

FIG. 4 is a transverse sectional view through a pair of modified hydraulic motors having a modified passage arrangement and illustrating the same connected in series for synchronous operation of the motors; and

FIG. 5 is a diagrammatic view illustrating the application of a pair of series connected motors for driving an elongated shaft at spaced points therealong to minimize twisting of the shaft.

The apparatus of the present invention is adapted for use either as a fluid pump or motor and relates to improvements in the fluid pumps or motors disclosed in my copending application, Serial No. 191,101 filed April 30, 1962, now Patent No. 3,150,603 issued September 29,

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1964. While the apparatus is adapted for use with either liquid or gaseous fluids, it is specifically designed and adapted for use with liquid fluids which are substantially incompressible and which present particular problems in avoiding hydraulic lock of the pistons in the cylinders during valving of the same. For convenience in describing the invention, it is hereinafter generally referred to as a fluid motor, it being understood that the apparatus is also adapted for operation as a pump when the shaft is driven.

The pump or motor in general employs a plurality of cylinders and pistons in each cylinder, with a cam mechanism for effecting sequential reciprocation of the pistons. Pairs of the pistons are reciprocated approximately 180° out of phase with each other and a valve mechanism is associated with one piston of each pair and arranged to valve the flows of fluid to each of the several cylinders while the valve apparatus associated with the other pistons of each pair are arranged to valve the flows of fluid from each of the cylinders whereby the supply and exhaust of fluid in each cylinder is controlled by valves associated with different pistons.

The valve apparatus associated with each piston employs a single main port and a single control port and each control port is connected to the piston chambers in at least two other cylinders in which the pistons are operated out of phase with each other. The phase relationship between the valves and the interconnected cylinders that are controlled by the valves is advantageously made such that when the valves are in a position blocking flow to the interconnected cylinders, the pistons in those cylinders are moving in relatively opposite directions so that fluid displaced from one cylinder will flow into the other and avoid an hydraulic lock.

Reference is now made more specifically to the preferred embodiments of the invention illustrated in the accompanying drawings. The pump includes a casing 10 having a plurality of cylinders therein and a shaft 11 and cam 12 for controlling reciprocation of the pistons in the cylinders. The pump or motor preferably employs six cylinders or multiples thereof and herein designed 15a-15f. Pistons designated 16a-16f are provided in the cylinders 15a-15f respectively and the pistons engage the cam 12 to be reciprocated thereby. Any suitable means may be provided for closing the ends of the cylinders and, as shown, caps 17 are threadedly or otherwise secured in the outer ends of the cylinders to close the same. Springs 18 are preferably interposed between the caps and the pistons to yieldably urge the pistons inwardly into engagement with the cam 12 and, as shown, the springs are conveniently located in recesses 19 and 20 in the cylinder heads and pistons respectively. When the device is operated as a fluid motor, the fluid pressure acting on the outer ends of the pistons hold the same firmly against the cam. In such applications, the springs 18 need only be relatively light weight springs sufficient to initially press the pistons against the cam to assure that the valves are in proper position when starting the device. However, if the device is operated as a pump in which the inlet pressure may drop below atmospheric pressure, then it is necessary to use somewhat heavier springs to hold the pistons against the cam when the pressure at the outer end of the pistons is below atmospheric pressure.

The pistons define piston chambers 22a-22f in the cylinders 15a-15f respectively, and the cam means 12 sequentially reciprocates the pistons to expand and contract the piston chambers. While the cylinders and cam means can be physically arranged in various different ways to achieve sequential reciprocation of the pistons in response to rotation of the cam means with the shaft, the cylinders are preferably arranged so as to extend generally radially of the shaft and a single annular cam

12 is provided to engage and reciprocate each of the pistons. The cam has its center C2 offset from the center C1 of the shaft and a plane designated P1 through the axis of the shaft and the axis of the cam means define the eccentric plane of the cam. In other words, this plane extends through the high point HP and the low point LP of the cam so that, as the cam is rotated, the pistons on one side of the eccentric plane of the cam move outwardly while the pistons on the opposite side of the eccentric plane of the cam move inwardly. In the six piston arrangement illustrated, the cylinders 15a-15f are angularly spaced apart approximately 60° and the pistons are reciprocated successively in approximately 60° phase relation. Thus, pairs of pistons such as 16a, 16d; 16b, 16e; and 16c, 16f are reciprocated approximately 180° out of phase with each other and are therefore in opposed relation to each other.

A valve apparatus is associated with each of the six pistons and cylinders for valving the flows to and from the piston chambers. The valve apparatus associated with one piston of each pair is used to valve the supply of fluid to all of the piston chambers and the valve apparatus associated with the other piston members of each pair is employed to valve the exhaust of fluid to all of the piston chambers. The valve apparatus is advantageously formed on the cylinders and pistons and each valve apparatus includes a single main port 25a-25f and a single control port designated 26a-26f respectively. While the main and control ports are herein diagrammatically shown as a single hole intersecting the respective cylinder, it is apparent that the ports could be in the form of an annular groove which extends around the respective cylinder. The main and inlet ports in each cylinder are axially spaced apart along the cylinder, and valve means is provided on the respective piston members for communicating the main and control ports in each cylinder with each other during approximately one-half revolution of the cam, and for blocking flow between the main and control ports of each cylinder during the other half of each revolution. As shown, the valve means on the pistons 16a-16f comprises an annular groove designated 27a-27f respectively, and which groove defines inner and outer valve faces 28 and 29 on each piston member.

In the six piston pump disclosed, the valve means on each piston member controls the flow of fluid in one direction to two separate piston chambers in which the pistons are operated out of phase with each other and out of phase with the valving piston. In other words, the piston chambers in selected pairs of cylinders are interconnected with each other and connected to the control ports on a different pair of cylinders. As shown in the drawings, the control ports 26a and 26d on the cylinders 15a and 15d are connected through passage means 31a and 31d to the piston chambers 22f and 22e, and the latter piston chambers are interconnected with each other by a passage means 32a. Similarly, the control ports 26b and 26e on the cylinders 15b and 15e are connected through passages 31b and 31e to the piston chambers 22c and 22d, and the latter piston chambers are interconnected by a passage 32b. In like fashion, the control ports 26c and 26f on the cylinders 16c and 16f are connected through passages 31c and 31f to the piston chambers 22b and 22a, and the latter piston chambers are interconnected by a passage means 32c. As previously mentioned, one valving piston of each opposed pair is employed to valve the flow of fluid to two piston chambers and the other valving piston of each pair is employed to valve the flow of fluid from each of the same two piston chambers. In the embodiment of FIGS. 1-3, fluid under pressure is supplied from a pump 35 through a pressure line 36 and flow reversing valve 37 to a supply line 38 connected through passages 38a, 38c and 38e to the main ports 25a, 25c and 25e on the cylinders that are angularly spaced apart approximately 120° from

each other. The fluid return line 41 leading to the reservoir 42 is also connected through the valve 37 to the exhaust passages 38b, 38d and 38f which are respectively connected to the main ports 25b, 25d and 25f.

The control ports 26a-26f of the several valves are arranged in relation to the valve faces 28 on the piston blocking flow through the respective control ports, when the cam 12 is in a position in which the eccentric plane P1 of the cam is disposed substantially normal to the axis of the pistons. Thus, as shown in FIG. 1, the plane P1 is disposed substantially normal to the axis of the pistons 16b and 16e and those pistons are positioned with the valve faces 28 thereof adjacent the inner edge of the ports 26b and 26e to block flow through these ports, both to and from the associated piston chambers 22c and 22d. However, as will be seen from FIG. 1, the pistons 16c and 16d in the blocked piston chambers 22c and 22d are disposed at relatively opposite sides of the eccentric plane P1 of the cam so that these pistons are moving in relatively opposite directions during the portion of the cycle when flow both to and from their piston chambers is blocked. Therefore, fluid being displaced from one blocked piston chamber 22c will flow into the other blocked piston chamber 22d and thereby avoid an hydraulic lock. This permits the valves to be timed with no overlap nor even a slight underlapping between the supply and exhaust from the cylinders to minimize leakage between the supply and return valves. In other words, the valves can be arranged so that the valve on the supply piston completely shuts off flow to the respective pair of piston chambers before the valve on the exhaust piston opens to exhaust fluid from those piston chambers without encountering an hydraulic lock.

When the cam is in the position shown in FIG. 1, one of the other pistons, located on one side of the eccentric plane of the cam valves the supply of fluid to two piston chambers and another one of the pistons, located at the other side of the eccentric plane of the cam, valves the exhaust of fluid from still another pair of cylinders. More particularly, fluid under pressure from the supply passage 38 is passed through the main port 25a and through control port 26a to the piston chambers 22f and 22e, while return flow from those chambers is blocked by the valve on piston 16d. Simultaneously, fluid from the piston chambers 22a and 22b is exhausted through the control port 26f and the piston 16f, while the supply of fluid to the chambers 22a and 22b is shut off by the valve on piston 16c.

FIG. 2 illustrates the cam angularly advanced approximately 30° clockwise from the position shown in FIG. 1. When the cam is in this position, the valve on piston 16a supplies fluid pressure to piston chambers 22f and 22e. The valve on piston 16b communicates piston chambers 22c and 22d to exhaust and the valve on piston 16f also communicates piston chambers 22a and 22b to exhaust. Thus, fluid under pressure is supplied to two piston chambers while fluid is being exhausted from four piston chambers. However, it will be noted that the piston chambers 22a and 22d are in opposed relation to each other and accordingly cancel. Thus, two pistons namely pistons 22e and 22f are active in this position of the cam to apply torque to the shaft.

FIG. 3 illustrates the cam in a third position angularly advanced 90° from the position shown in FIG. 1 and 60° from FIG. 2. In this position, the valve on piston 16b communicates chambers 22c and 22d to exhaust. The valve on 16c applies pressure to the piston chambers 22a and 22b and the valve on piston 16a supplies fluid pressure to piston chambers 22f and 22e. Thus, at this position fluid under pressure is supplied to four piston chambers and exhausted from two piston chambers. However, the piston chambers 22c and 22b are in opposed relation to each other and the forces on those pistons effectively cancel. Accordingly, only two pistons namely

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piston 22*f* and 22*a* are active in this position of the cam to apply torque to the shaft.

While the apparatuses herein described as having the pressure supplied to one set of ports 25*a*, 25*c* and 25*e* and exhausted from the other ports 25*b*, 25*d* and 25*f*, it is apparent that the reversing valve 37 can be operated to reverse the flow of fluid to the motor and reverse the main ports in the cylinders to which pressure is applied and exhausted. This effects reversal of the direction of operation of the motor. Accordingly, while the specification and claims herein sometimes refer to ports as being pressure ports and other ports as being exhaust ports, it is to be understood that these ports do not always have to remain pressure or exhaust ports and that the pressure and exhaust can be reversibly applied to these ports to reverse the operation of the pump or motor. Further, while the control ports as shown in FIGS. 1-3 are all arranged so that the valves on the pistons effect communication between the respective main and control ports as the pistons move outwardly in the cylinders from their mid-position, the control ports could all be reversed so that the valves on the pistons effect communication between the respective main and control ports as the pistons move inwardly from their mid-position. Alternatively, a combination of the two valve arrangements, described hereinafter, may be used.

A pair of fluid motors designated 50*a* and 50*b* are illustrated in FIG. 4 and have a modified valve arrangement on one pair of cylinders. These motors are the same as previously described in connection with FIGS. 1-3 and like numerals are used to designate parts on both of the motors which correspond to those in the pumps and motors previously described. The modified structure is indicated by the same numeral followed by the suffix (''). In the embodiment of FIG. 4, fluid under pressure is still supplied to the main port of one cylinder of each pair of opposed cylinders. However, in this embodiment, fluid pressure is supplied to the main ports associated with three adjacent cylinders angularly spaced apart approximately 60° and fluid is exhausted from the main ports associated with three other cylinders angularly also spaced apart 60°. Thus, as shown, the pressure passage 38 from the reversing valve is connected through passages 38*a*' and 38*b*' to the main ports 25*c*' and 25*d*' in cylinders 15*c* and 15*d* and a fluid supply passage 38*c*' extends from the cylinder 15*d* to the port 25*e*' in the cylinder 15*e*. Similarly, fluid is simultaneously exhausted from the main ports in the three adjacent cylinders. For this purpose, the return line 38*d*' is connected through a passage 38*e*' to the main port 25*a*' in the cylinder 15*a* and to the main port 25*b*' in the cylinder 15*b*. A further return passage 38*f*' communicates the cylinder 15*a* with the main port in the cylinder 15*f*. Thus, fluid under pressure is simultaneously applied to one of the main ports such as 25*c*', 25*d*' and 25*e*' of each pair of opposed cylinders while fluid is simultaneously exhausted from the other main port 25*a*', 25*b*' and 25*f*' of each pair. As will be seen from a comparison of the pump or motor of FIG. 4 with that shown in FIG. 1, the net effect of the above is to reverse the application of fluid pressure to one pair of opposed cylinders such as cylinders 15*a* and 15*d*, while the supply and exhaust of fluid from the other cylinders remains the same. In order to effect valving in proper timed relation, it is necessary to reverse the position of the pistons at which valving occurs in that one pair of cylinders. As shown, the control ports designated 26*a*' and 26*d*' and the cylinders 15*a* and 15*d* are moved inwardly so that valving occurs when the pistons approach the inner one-half of their stroke. At that time, the valve face 29 on the inner end of the groove 27 uncovers the control ports to effect valving in proper timed relation. The above described motor operates in the same manner as that described in connection with FIGS. 1-3 but has certain advantages thereover in that it simplifies the problem of coring the casing

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to provide the passages for supplying and exhausting fluid from the main ports.

In the fluid motors described above, one set of valves is employed to valve the flow of fluid to the several piston chambers while a different set of valves is employed to valve the flow of fluid from the several piston chambers. It has been found that a pair of such fluid motors can be operated in substantial synchronism by connecting the fluid motors in series. Thus, as shown in FIG. 4, the pump 35 has its supply line 36 connected to one set of main ports 25*c*', 25*d*' and 25*e*' in one fluid motor 50*a* and the other set of the main ports 25*f*', 25*a*' and 25*b*' in that fluid motor are connected through a line 60 to the inlet main ports 25*c*', 25*d*' and 25*e*' in the second fluid motor 50*b*. The exhaust fluid ports 25*f*', 25*a*' and 25*b*' in the second motor 50*b* are then connected to the return or sump 42 through a line 61. Thus, fluid from the pump 35 is passed in series through the motors. Since the same fluid passes through both motors, the latter operate in substantial synchronism. Moreover, since the valving functions of supply and exhaust are controlled by the valves on separate pistons, the back pressure on the second motor does not produce an hydraulic lock in the first motor.

The dual motors operated in synchronism are advantageously employed in connection with driving a common shaft to inhibit twisting of the shaft under load. In some applications such as the cultivator 65 shown in FIG. 5, the shaft 66 is subjected to relatively high torque loads along the length thereof. If the entire propulsive force is applied to one end of the shaft, there is a substantial amount of twist in the shaft which frequently results in rupture or failure of the same. In accordance with the present invention, a pair of such motors 50*a* and 50*b* have their shafts 11 nonrotatably connected to the common shaft 66 and, the motors are operated in series through lines 60 and 61 as previously described so that they will drive both ends of the shaft 66 in substantial synchronism to inhibit twisting of the shaft under load.

From the foregoing it will be seen that the fluid pumps or motors described achieve valving of the flows of fluid to and from the several cylinders in sequence and that the valving of fluid to the several cylinders is controlled by valves on one set of pistons while the valving of the fluid from the several cylinders is controlled by the valves on a different set of pistons. The supply and exhaust of fluid from the several cylinders is thus controlled by separate valves so as to avoid flow reversal in the valves and to minimize leakage between the supply and exhaust lines. The valves are so arranged that each employs only a single main port and a single control port so that manufacture of the pump or motor is facilitated. Each valve controls the supply or exhaust of fluid to two other cylinders and the pistons in these cylinders are operated out of phase with each other such that, at the time that the flow to and from an interconnected pair of cylinders are moving in relatively opposite directions to avoid hydraulic lock.

While there has been described herein and illustrated in the accompanying drawings certain preferred embodiments of the present invention, it is to be understood that various modifications, omissions and refinements which depart from the disclosed embodiments may be adapted without departing from the spirit and scope of this invention.

I claim:

1. A piston type fluid motor comprising, a casing having a plurality of pairs of cylinders and a pair of piston members in each pair of cylinders each defining a piston chamber at one end of the respective cylinder, a shaft and cam means on the shaft controlling reciprocation of the piston members of each pair substantially 180° out of phase with each other and at a preselected phase relation to the piston members of the other pairs, the cylinders each having a single main port and a single control port and the piston members each having valve means thereon controlling flow between the main and control ports in the

respective cylinder, a fluid supply line connected to one main port in each pair of cylinders and a fluid exhaust line connected to the other main port in each pair of cylinders, and passage means connecting the control ports in each pair of cylinders to the piston chamber in at least one other cylinder whereby the valve means on one piston of each pair operates to control the supply of fluid pressure to said one other cylinder and the valve means on the other piston member of each pair operates to control exhaust of fluid pressure from said one other cylinder.

2. A piston type fluid pump or motor comprising, a casing having at least three pairs of cylinders and a pair of piston members in each of said pairs of cylinders, each piston member defining a piston chamber at one end of the respective cylinder, a shaft and cam means on the shaft controlling reciprocation of the piston members of each pair substantially 180° out of phase with each other and at a preselected phase relation to the piston members of the other pairs, the cylinders each having a single main port and a single control port and the piston members each having valve means thereon controlling flow between the main and control ports in the respective cylinder, a fluid supply line connected to one main port in each pair of cylinders and a fluid exhaust line connected to the other main port in each pair of cylinders, and passage means connecting the control ports in each pair of cylinders to the piston chambers in two other cylinders whereby the valve means on one piston of each pair operates to control supply of fluid pressure to the piston chambers in two other cylinders and the valve means on the other piston member of each pair operates to control exhaust of fluid from the piston chambers in those two cylinders.

3. A piston type fluid pump or motor comprising, a casing having at least three pairs of cylinders and a pair of piston members in each of said pairs of cylinders, each piston member defining a piston chamber at one end of the respective cylinder, a shaft and cam means on the shaft controlling sequential reciprocation of the piston members with a phase angle between successive piston members of approximately $360^\circ/n$ where n is the number of piston members, the piston members of each pair being reciprocated substantially 180° out of phase with each other, the cylinders each having a single main port and a single control port and the piston members each having valve means thereon controlling flow between the main and control ports in the respective cylinder, a fluid supply line connected to one main port in each pair of cylinders and a fluid exhaust line connected to the other main port in each pair of cylinders, and passage means connecting the control ports in each pair of cylinders to piston chambers associated with two piston members operated at a phase angle of $360^\circ/n$ relative to each other whereby the valve means on one piston of each pair operates to control supply of fluid pressure to the piston chambers in two other cylinders and the valve means on the other piston member of each pair operates to control exhaust of fluid from the piston chambers in those two cylinders.

4. A piston type fluid pump or motor comprising, a casing having at least three pairs of cylinders and a pair of piston members in each of said pairs of cylinders, each piston member defining a piston chamber at one end of the respective cylinder, a shaft and cam means on the shaft controlling sequential reciprocation of the piston members with a phase angle between successive piston members of approximately $360^\circ/n$ where n is the number of piston members, the cylinders each having a single main port and a single control port and the piston members each having valve means thereon controlling flow between the main and control ports in the respective cylinder, a fluid supply line connected to one main port in each of said pairs of cylinders and a fluid exhaust line connected to the other main port in each of said pairs of cylinders, said cylinders being arranged in at least three sets of cylinders having passage means interconnecting the piston chambers in the cylinders of each set, and passage means

connecting the control ports in each pair of cylinders to the piston chambers in one of said sets of cylinders whereby the valve means on each pair of cylinders alternately supplies and exhausts fluid from the several piston chambers in a respective set of cylinders.

5. A piston type pump or motor comprising, a casing having six cylinders and a piston member in each cylinder defining a piston chamber at one end of the respective cylinder, a shaft and cam means on the shaft controlling reciprocation of the pistons in successive approximately 60° phase relation whereby selected pairs of said pistons are reciprocated approximately 180° out of phase with each other, the cylinders each having a single main port and a single control port and valve means thereon controlling flow between the main and control ports in the respective cylinder, a fluid supply line connected to one main port associated with each of said selected pairs of pistons and a fluid exhaust line connected to the other main port associated with each of said selected pairs of pistons, the piston chambers in said cylinders being grouped in three sets containing two piston chambers in each set and having passage means interconnecting the two piston chambers of each set, and passage means connecting the control ports associated with each of said selected pairs of piston members to one of said sets of piston chambers.

6. A piston type pump or motor comprising, a casing having six cylinders and a piston member in each cylinder defining a piston chamber at one end of the respective cylinder, a shaft and cam means on the shaft controlling reciprocation of the pistons in successive approximately 60° phase relation whereby selected pairs of said pistons are reciprocated approximately 180° out of phase with each other, the cylinders each having a single main port and a single control port and valve means thereon controlling flow between the main and control ports in the respective cylinder, a fluid supply line connected to one main port associated with each of said selected pairs of pistons and a fluid exhaust line connected to the other main port associated with each of said selected pairs of pistons, the piston chambers in said cylinders being grouped in three sets containing two piston chambers in each set and having passage means interconnecting the two piston chambers of each set, the piston members associated with the piston chambers of each set being reciprocated approximately 60° out of phase with each other, and passage means connecting the control ports associated with each of said selected pairs of piston members to one of said sets of piston chambers, the piston members of each set being reciprocated out of phase with the piston members which control the application of fluid pressure thereto.

7. A piston type pump or motor comprising, a casing having first, second, third, fourth, fifth and sixth cylinders and a piston member in each cylinder defining a piston chamber at one end of the respective cylinder, a shaft and cam means on the shaft controlling reciprocation of the first through the sixth piston member in successive substantially 60° phase relation whereby selected pairs of said pistons are reciprocated substantially 180° out of phase with each other, each of said cylinders having a single main port and a single control port and each of said piston members having valve means thereon controlling flow between the main and control ports in the respective cylinder, a fluid supply line connected to one main port in the pair of cylinders associated with each of said selected pairs of pistons and a fluid exhaust line connected to the other main port of each of said pairs of cylinders, a first passage means interconnecting the piston chambers in the first and second cylinders and connecting those piston chambers to the control ports on the sixth and third cylinders; a second passage means interconnecting the piston chambers on the third and fourth cylinders and connecting those piston chambers to the control ports on the second and fifth cylinders; and a

third passage means interconnecting the piston chambers in the fifth and sixth cylinders and connecting those piston chambers to the control ports on the first and fourth cylinders.

8. The combination of claim 7 wherein the fluid supply line is connected to the main ports in three of the cylinders associated with pistons that are reciprocated approximately 120° out of phase with each other and the fluid return line is connected to the main ports on the other of said cylinders.

9. The combination of claim 7 wherein the fluid supply line is connected to the main ports in three of the cylinders associated with pistons that are reciprocated in successive approximately 60° phase relation and the fluid return line is connected to the main ports on the other three cylinders.

10. A piston type pump or motor comprising, a casing having six cylinders angularly spaced apart approximately 60° providing opposed pairs of cylinders angularly spaced apart approximately 180°, a piston member in each cylinder defining a piston chamber at one end of the respective cylinder, a shaft and cam means on the shaft controlling reciprocation of the piston members in successive approximately 60° phase relation whereby opposed pairs of piston members are reciprocated approximately 180° out of phase with each other, each of said cylinders having a single main port and a single control port and each of said piston members having valve means thereon for controlling flow between the main and control ports in the respective cylinder, a fluid supply line connected to one main port in each opposed pair of cylinders and a fluid exhaust line connected to the other main port in each opposed pair of cylinders, said cylinders being grouped in three sets containing two angularly adjacent cylinders in each set having passage means interconnecting the two piston chambers in each set, and passage means connecting the control ports in each of said opposed pairs of cylinders to the piston chambers in a respective one of said sets of cylinders.

11. A piston type pump or motor comprising a shaft and an annular cam eccentric to the shaft, a plane through the axes of the shaft and cam defining the eccentric plane of the cam, a casing having six cylinders extending generally radially of the shaft and angularly spaced apart approximately 60° providing opposed pairs of said cylinders angularly spaced approximately 180° apart, a piston member in each cylinder engaging the cam, the piston members being disposed in a mid-position when the eccentric plane of the cam is disposed approximately normal to the axis of the respective piston member and the cam controlling reciprocation of the piston members in successive approximately 60° phase relation, said cylinders each having a single main port and a single control port, valve means on each piston member operative when the piston member is in its mid-position to substantially block flow between the respective main and control portion and operative when the piston member is moved in one direction from its mid-position to communicate the respective main and control ports, a fluid supply line communicating with one main port in each opposed pair of cylinders and a fluid exhaust line communicating with the other main port in each opposed pair of cylinders, said cylinders being grouped in three sets containing two angularly adjacent cylinders in each set having passage means interconnecting the two piston chambers in each set, and passage means connecting the control ports in each of said opposed pairs of cylinders to the piston chambers in a respective one of said sets of cylinders.

12. The combination of claim 11 wherein said fluid

supply line is connected to the main ports in alternate ones of said cylinders that are angularly spaced apart approximately 120° and the fluid exhaust line is connected to the main ports in the other three cylinders, the control ports and the valve means in all of the cylinders being so arranged that each valve means communicates the main and control ports in the respective cylinder in response to movement of the piston members in the same direction from their mid-position.

13. The combination of claim 11 wherein said fluid supply line is connected to the main ports in three angularly adjacent cylinders and the fluid exhaust line is connected to the main ports in the other three angularly adjacent cylinders, the control ports and valve means in one pair of opposed cylinders being so arranged that the valve means of that pair communicate the main and control ports in the respective cylinder in response to movement of those piston members in a first direction from their mid-position and the valve means and control ports in the other cylinders being so arranged that the valve means in said other cylinders communicate the main and control ports in the respective cylinders in response to movement of the piston members in the other direction from their mid-position.

14. The combination of claim 1 including a second motor constructed in accordance with claim 1 and of like size, means for operating said motors in synchronism comprising, pump means having a pressure line connected to the fluid supply line of one motor and having a return line connected to the fluid exhaust line of said second motor and conduit means connecting the fluid exhaust line of said one motor to the fluid supply line of said second motor whereby to pass fluid through the first and second motors in series.

15. In combination, first and second fluid motors of like size, said motors each comprising a casing having a plurality of pairs of cylinders and a pair of piston members in each pair of cylinders each defining a piston chamber at one end of the respective cylinder, said motors each including cam means controlling reciprocation of the piston members of each pair substantially 180° out of phase with each other and at a preselected phase relation to the piston members of the other pairs, one cylinder of each pair of cylinders in each motor having an inlet port and the other cylinder of each pair of cylinders in each motor having an outlet port, the cylinders of both motors each having at least one control port and passage means connecting the control ports in each of said pairs of cylinders to at least one piston chamber, and means for operating said motors in synchronism comprising, pump means having a pressure line connected to the inlet ports of said first motor and a return line connected to the outlet ports of said second motor, and conduit means connecting the outlet ports of said first motor to the inlet ports of said second motor to pass fluid through the first and second motors in series.

16. The combination of claim 15 wherein the cam means on the first and second motors are connected to a common shaft at spaced points therealong.

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