

April 5, 1960

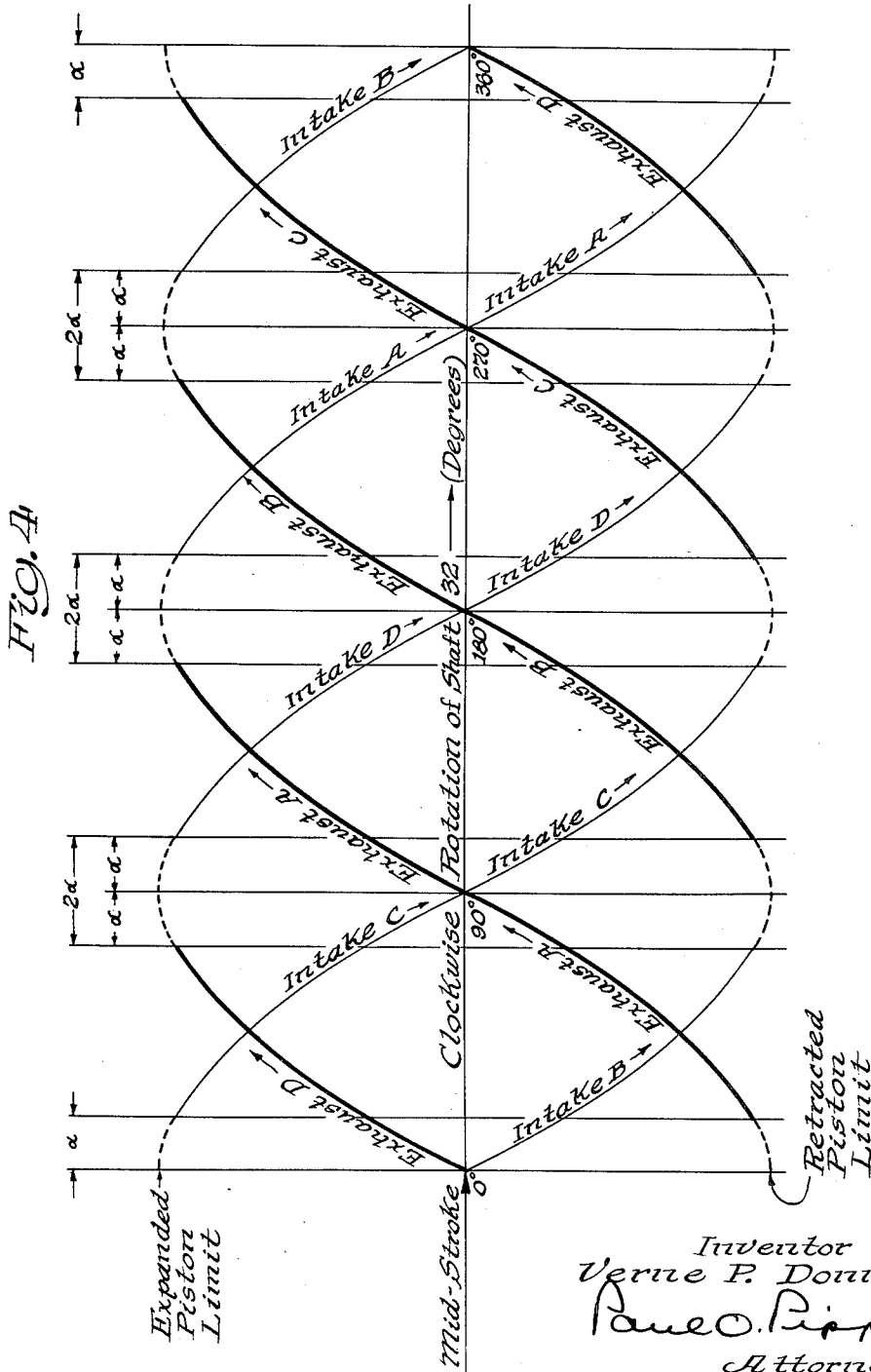
V. P. DONNER

2,931,312

POSITIVE DISPLACEMENT PUMP

Filed Nov. 7, 1957

2 Sheets-Sheet 1



April 5, 1960

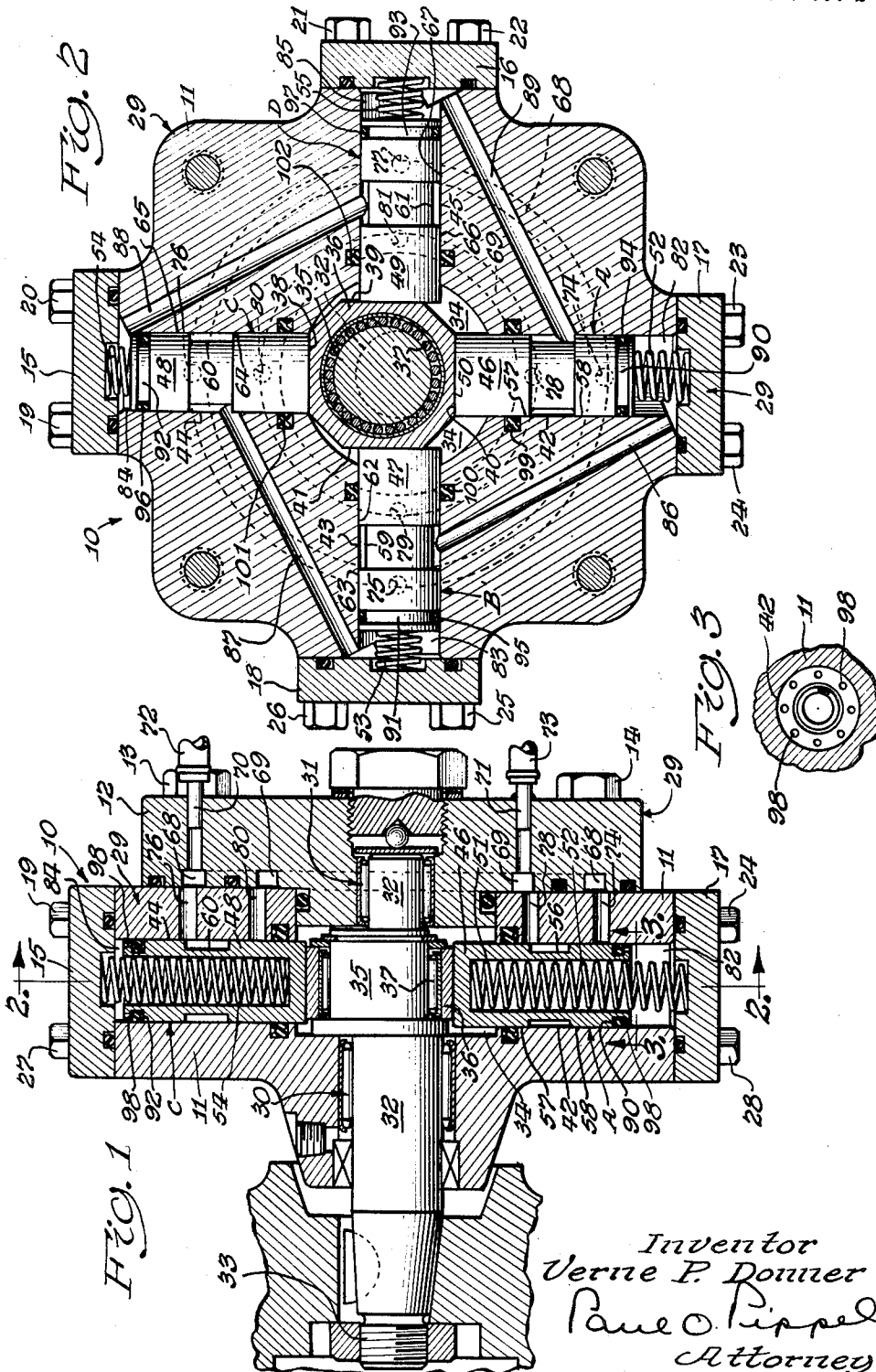
V. P. DONNER

2,931,312

POSITIVE DISPLACEMENT PUMP

Filed Nov. 7, 1957

2 Sheets-Sheet 2



1

2,931,312

POSITIVE DISPLACEMENT PUMP

Verne P. Donner, Palatine, Ill., assignor to International Harvester Company, Chicago, Ill., a corporation of New Jersey

Application November 7, 1957, Serial No. 695,059

7 Claims. (Cl. 103—174)

This invention relates to a positive displacement piston type pump. More in particular this invention relates to a reversible multi-cylinder pump of the positive displacement type wherein one piston serves as a valving means for another piston in a phased relation.

In certain types of mechanisms, there is need for a positive delivery type pump which functions at very low speed and possesses characteristics of none or at most a slight slip or internal leakage. For example certain types of hydraulic control valves are operated by means of a secondary hydraulic control circuit which may conveniently be pressurized by the pump of this invention. A specific example of such an application is in a hydraulic steering mechanism for a two-wheeled tractor and associated trailer wherein the main hydraulic control valve is operable in response to fluid pressure in a secondary fluid circuit. The positive displacement pump of this invention in such application would be drivingly connected to the tractor steering wheel and the pump's displaced fluid is directed to actuate the main hydraulic control valve whereby the steering motors are controllably energized. For a more detailed description of such a steering device wherein the pump of this invention is adaptable reference is made to the pending patent application of Verne P. Donner and William W. Henning entitled "Fluid Power Steering System," filed under Serial No. 653,802 on April 19, 1957, and assigned to the assignee herein.

It is a prime object of this invention to provide an extremely low speed positive displacement pump.

A further object of this invention is to provide a positive displacement pump wherein the fluid slippage there-through is essentially eliminated.

A still further object of this invention is to provide a positive displacement pump of a multicylinder type where the piston of one cylinder is operative as a valve means for controlling the intake of fluid into another cylinder and subsequent discharge therefrom.

Another object of this invention is to provide a positive displacement multi-cylinder piston pump according to the preceding objects wherein the pistons are actuated in balanced multi-phase relation with respect to each other so that at least one cylinder is discharging fluid at any point during a cycle of operation.

These and other desirable and important objects inherent in and encompassed by the invention will be more readily understood from the ensuing description, the appended claims and the annexed drawings wherein:

Figure 1 is a side elevation view of a preferred embodiment of the invention in section taken along the vertical plane passing through its central axis.

Figure 2 is an end view taken in section along the line 2—2 of Figure 1.

Figure 3 is a view of the outer end of a piston taken along the line 3—3 of Figure 1 illustrating fluid communication means to a fluid pressure compressible element.

Figure 4 is a diagram illustrating the balanced multi-

2

phase relation of the pistons in relation to each other at all points in a complete cycle of operation.

With continued reference to the drawings it will be seen from Figure 1 that the pump unit of this invention generally indicated at 10 may comprise a stationary structure 11 having an end plate 12 fastened rigidly thereto such as by bolts two of which are shown at 13 and 14 and head plates 15, 16, 17 and 18 held rigidly to the structure 11 by a plurality of fasteners such as for example bolts shown at 19 through 28. Since the structure 11 with end plate 12 and head plates 15 through 18 are separable for manufacturing reasons, they are for purposes of this invention rigidly connected together to form what may conveniently be termed a block member generally indicated at 29.

The block member 29 is provided with a pair of axially aligned bearings generally indicated at 30 and 31. Journalled for rotation in the bearings 30 and 31 is a drive shaft 32 adapted to be rotated by a source of power (not shown) connected to the threaded portion 33 as best illustrated in Figure 1. The central portion of the block member 29 is provided with a hollow space or crankcase 34. The portion of the drive shaft 32 within the crankcase 34 is provided with an eccentric lobe or crank 35 to form a commonly known crankshaft. Journalled to the crank 35 through bearing 37 in rotatable relation is a cam 36 having actuating surfaces 38 through 41 as best shown in Figure 2. It will become more apparent in a later portion of this description that the cam 36 does not rotate about its central axis but instead its longitudinal axis moves in a circular motion about the axis of the drive shaft 32 responsive to rotational movement of the crank 35.

The block member 29 is provided with four cylinders generally indicated at A, B, C and D as best illustrated in Figure 2. The cylinders A, B, C and D may conveniently be constructed and positioned as follows. The block member 29 may be provided with four bores 42, 43, 44 and 45 each opening at its inner end into the crankcase 34 as best shown in Figure 2. The axis of each of the bores 42 through 45 is positioned in a common plane which plane is perpendicular to the longitudinal axis of the crankshaft or drive shaft 32. Thus the axis of each of the bores 42 through 45 is positioned perpendicular to the longitudinal axis of the drive shaft 32. Furthermore the axis of bore 42 is perpendicular to the axes of bores 43 and 45 and in axial alignment with bore 44. Thus each of the bores 42 through 45 is positioned in the block member 29 in transverse relation with respect to the longitudinally disposed crankshaft or drive shaft 32.

Slidably disposed in each of the bores 42 through 45 are, respectively, pistons 46, 47, 48 and 49 as best illustrated in Figure 2. Each of the pistons are constructed identically alike and accordingly it is deemed only necessary to describe one in detail and it may correctly be assumed that the other three pistons are each constructed similarly. As may be seen from Figure 1 the piston 46 is constructed to fit slidably in the bore 42. The inner end of the piston 46 is provided with a face 50 adapted to seat firmly on the actuating surface 40 of the cam 36. The piston 46 is provided with a recessed portion 51 within which is disposed a spring 52 under compression. The spring 52 is in an abutting relation to the outer end to the head plate 17 and its inner end engaging the piston 46 thus urging the inner end face 50 of the piston 46 into abutting relation with actuating surface 40 of the cam 36. In similar manner springs 53, 54 and 55 are, respectively, provided for pistons 47, 48 and 49. In the central peripheral portion of the piston 46 is disposed an annular shaped circumferential groove 56 as shown in Figures 1 and 2. The

presence of the groove 56 forms what may conveniently be termed lands 57 and 58 for a purpose to be described later. Pistons 47, 48 and 49 similarly are each provided respectively with circumferential grooves 59, 60 and 61 having associated lands 62 through 67 as shown best in Figure 2.

The end plate 12 of the block member 29 is provided with a pair of concentrically disposed annularly shaped passages 68 and 69 communicatively connected, respectively, to tubes 70 and 71 and hose 72 and 73. The passage 68 is provided with four ports 74 through 77 in respective communication with bores 42 through 45. The position of the port 74 in the outer end portion of the bore 42 is such that as the piston 46 reciprocates the port 74 is registerable alternately with circumferential groove 56 and the land 58. Likewise ports 75, 76 and 77 are positioned respectively in the outer end portion of the bores 43, 44 and 45 such that as the pistons 47, 48 and 49, respectively, reciprocate each of the ports 75, 76 and 77 is alternately registerable with respective grooves 59, 60 and 61 and lands 63, 65 and 67. The passage 69 is also provided with ports 78 through 81 in respective communication with bores 42 through 45. The position of the port 78 in the inner end portion of the bore 42 is such that as the piston 46 reciprocates the port 78 is registerable alternately with circumferential groove 56 and the land 57. Likewise ports 79, 80 and 81 are positioned respectively in the inner end portion of the bores 43, 44 and 45 such that as the pistons 47, 48 and 49, respectively, reciprocate each of the ports 79, 80 and 81 is alternately registerable with respective grooves 59, 60 and 61 and lands 62, 64 and 66.

At this point it should be noted that with reference to piston 46 the length of the circumferential groove 56, as measured by the distance between the lands 57 and 58, is slightly less than the distance between the ports 74 and 78. Thus the port 74 is never in direct communication with port 78 irrespective of the position of the piston 46. A similar relation exists with reference to pistons 47, 48 and 49 and the respective lands and circumferential grooves associated therewith.

Referring now to Figure 2 it will be seen that pistons 47 and 49 are both at mid-stroke position. That is to say that the pistons 47 and 49 are shown in a position exactly one-half the distance from the innermost limit and the outermost limit of reciprocable movement. It will be observed from Figure 2 that when the pistons 47 and 49 are in mid-stroke position, the ports 75 and 79 are equidistant from the groove 59 and ports 77 and 81 are equidistant from the groove 61. A similar relation exists with reference to pistons 46 and 48 and the respective ports 74, 78, 76 and 80 and grooves 56 and 60 when pistons 46 and 48 are moved to mid-stroke position.

Disposed at the outer end portions of each of the bores 42 through 45 there are chambers 82 through 85 formed with the outer ends of pistons 46 through 49, respectively, and head plates 17, 18, 15 and 16 respectively. The chamber 82 is connected to the bore 43 and circumferential groove 59 in fluid communicative relation by the conduit 86 as shown in Figure 2. The chamber 83 is connected to the bore 44 and circumferential groove 60 in fluid communicative relation by conduit 87. The chamber 84 is connected to the bore 45 and circumferential groove 61 in fluid communicative relation by conduit 88. The chamber 85 is connected to the bore 42 and circumferential groove 56 in fluid communicative relation by conduit 89 as best shown in Figure 2.

Now in order to prevent fluid locking during certain positions in operation each of the chambers 82 through 85 is provided with access means to a fluid pressure compressible element which element functions to absorb fluid pressure surges as will be discussed later. For convenience each of the pistons 46 through 49 adjacent

the outer ends thereof is provided with a small annular groove 90, 91, 92 and 93, respectively, shown in Figure 2. Within each of the grooves 90 through 93 is disposed a fluid pressure compressible element 94, 95, 96 and 97, respectively. The elements 94 through 97 may be comprised of a relatively soft material which preferably is not permeated or injured by the fluid used in the system. For example a felt material has been found quite satisfactory. Furthermore by positioning the elements 94 through 97 in respective grooves 90 through 93 a dual purpose may be served in that they also act as sealing rings between the pistons and their respective bores. Now in order to communicate the fluid pressure compressible elements 94 through 97 with respective chambers 82 through 85, it will be evident from Figure 3 that each of the pistons 46 through 49 is provided with a plurality of small holes 98 which permits access of the fluid in the chambers to the respective elements. Thus when a pressure surge occurs in a chamber the corresponding compressible element is available to absorb a portion of the pressure for reasons to be discussed later.

Because this type of pump is peculiarly adaptable for very slow speed and reversible operation it should be understood that the manufacturing tolerances for slidably fitting the pistons 46 through 49 should be held to a minimum. Furthermore the elements 94 through 97 should be fitted in sealing relation in their respective grooves 90 through 93 to prevent leakage of fluid thereby. In addition conventional sealing means should be provided at 99 through 102 to prevent leakage of fluid from the respective grooves 56, 59, 60 and 61 into the crankcase 34.

Operation

A complete cycle of operation for the pumping action of one cylinder will first be described. For purpose of reference to the chart shown as Figure 4 it will be assumed that at the commencement of one cycle of operation the pistons of the cylinders A, B, C and D are positioned as shown in Figure 2. Also it should be borne in mind that one complete cycle of operation requires one full revolution of the crankshaft 32 and it will be assumed that the shaft 32 will be rotated in a clockwise direction as viewed in Figure 2.

It will be seen from Figure 2 that the piston 46 of cylinder A is in a fully retracted position and its operation will first be described. It will also be noted that piston 47 of cylinder B is in mid-stroke position and will retract further inwardly upon clockwise rotation of shaft 32. Piston 48 of cylinder C is in a fully expanded position and will commence retraction upon clockwise movement of shaft 32. Piston 49 of cylinder D is in mid-stroke position and will expand further outwardly upon clockwise rotation of the shaft 32.

From the previous cycle of operation chamber 82 of cylinder A is filled with fluid and flow of fluid in the conduit 86 is blocked because from the position of piston 47 of cylinder B it will be seen that the circumferential groove 59 is not in registration with either of the ports 75 and 79. Therefore at this point the fluid in chamber 82 and conduit 86 is hydraulically confined therein.

Now referring to Figure 4 it will be seen that the chart consists of four cosine curves, A, B, C and D, plotted 90° apart in multi-phased relation. Consider first the curve A which illustrates graphically the motion of piston 46 of cylinder A. As the shaft 32 commences to rotate clockwise to an angular displacement of α degrees the fluid in the chamber 82 of cylinder A remains in an hydraulically confined condition because no discharge path is established. The compression or pressure surge of the fluid in the chamber 82 due to the outward movement of piston 46 during rotation of shaft 32 to an angular displacement of α degrees, is absorbed by the fluid pressure compressible element 94 thus allowing the piston 46 to move. In practice construction providing an angle of 18° for α has been successfully

used. When α is 18° it will be noted by simple mathematical analysis that the average rate of movement of piston 47 of cylinder B is about six times as fast as that of piston 46 of cylinder A. Thus an 18° angular displacement of the shaft 32 clockwise moves piston 47 a distance of about 15.45% of the length of its stroke while at the same time piston 46 of cylinder A moves about 2.45% of the length of its stroke.

When the shaft 32 has been rotated clockwise through an angular displacement of α degrees, piston 47 of cylinder B will have retracted inwardly to a point where the land 62 no longer closes the port 79 thus allowing discharge of the fluid in the chamber 82 through the conduit 86 and circumferential groove 59 into port 79 and out through the passage 69. Referring to curve A of Figure 1 it will be seen that cylinder A will continue to discharge or exhaust fluid into passage 69 until angular displacement of the shaft 32 reaches $180-\alpha$ degrees. During this interval the valve means in cylinder B maintains communicative relation between port 79 and groove 59.

Now as the shaft 32 approaches an angular displacement of $180-\alpha$ degrees, the piston 47 of cylinder B will have passed a fully retracted position and has moved outwardly to a point where the land 62 is closing off the flow of fluid from chamber 82 through the port 79. Thus the fluid in chamber 82 is again hydraulically confined. Since the piston 46 has not reached its outward limit, the fluid pressure compressible element 94 will again absorb the pressure surge arising from the outward movement of piston 46 responsive to the rotation of shaft 32 from an angular displacement of $180-\alpha$ degrees to 180° . At this point one-half of the operating cycle has been completed and piston 46 has reached its outward limit position similar to the position shown for piston 48 of cylinder C in Figure 2.

The second half of the operation cycle of cylinder A is confined to the inward or retractive movement of piston 46 whereby the chamber 82 is refilled with fluid from passage 68 through the valve means in cylinder B to the conduit 86 flowing in the opposite direction from that described in the first half of the cycle. As the crankshaft 32 proceeds to move the cam 36 from an angular displacement of 180° to $180+\alpha$ degrees the piston 46 commences to retract inwardly. During the interval of angular displacement of shaft 32 from $180-\alpha$ degrees to $180+\alpha$ degrees, the lands 62 and 63 of piston 47 cover both ports 75 and 79. As the angular displacement of shaft 32 approaches $180+\alpha$ degrees, the piston 47 of cylinder B will have moved outwardly to a point where the land 63 begins to uncover the port 75 thereby communicating the passage 68 with the chamber 82 through port 75, circumferential groove 59 and conduit 86. Thus fluid from the passage 68 commences to be drawn into the chamber 82 responsive to inward or retractive movement of the piston 46. Now as the angular displacement of the shaft 32 proceeds from $180+\alpha$ degrees to $360-\alpha$ degrees fluid from the passage 68 will continue to be drawn into the chamber 82. However, as the angular displacement of the shaft 32 approaches $360-\alpha$ degrees the piston 47 of cylinder B will have passed its outward limit and retracted inwardly to a point where the land 63 will again reach a position to close the port 75 thus terminating further intake of fluid from the passage 68 into the chamber 82.

Completion of the cycle of operation by the angular displacement of the shaft 32 from $360-\alpha$ degrees to 360° (0°) moves the piston 46 to the limit of its inward or retractive stroke creating a partial vacuum in the chamber 82 and conduit 86 which is at least partly compensated by the element 94.

Thus a complete cycle of operation has been described for cylinder A having its valve means positioned in cylinder B which pumps fluid from the passage 68 and exhausts it into passage 69 responsive to clockwise rota-

tion of the shaft 32 as viewed in Figure 2. If the shaft 32 is rotated in the opposite direction the flow of fluid will be in the reversed direction from that just described or in other words intake fluid will be drawn from passage 69 and exhausted into passage 68.

From the above description it can be seen that in order for the valving means in cylinder B to function efficiently for valving the flow of fluid to and from cylinder A through the conduit 86, the piston 47 in the cylinder B should be phased in relation to piston 46 of cylinder A at one-quarter cycle apart. Thus when the piston 46 is moving at its slowest average speed (during movement within the angular displacement of the shaft 32 in α degrees as discussed previously) the piston 47 governing the valving for cylinder A is moving at its maximum average speed for the same interval.

From the above discussion it becomes readily apparent that a pump unit of this kind is best comprised of four cylinders positioned in a balance multi-phase relation to each other as shown in Figure 2. Thus it will be seen from Figure 4 that if each of the four cylinders A, B, C and D are phased at one-quarter cycle apart in balanced multi-phased relation then the pumping unit will deliver fluid under pressure from at least one cylinder in all-stages of rotation of the shaft 32. To illustrate it will be seen from Figure 4 that rotation of shaft 32 from 0° to α degrees cylinder D is exhausting fluid while cylinder B is taking or drawing fluid and cylinders A and C are neither taking or exhausting fluid. From α to $90-\alpha$ degrees cylinders A and D are delivering fluid under pressure while cylinders B and C are drawing fluid. From $90-\alpha$ to $90+\alpha$ degrees cylinder A delivers fluid under pressure and cylinder C is drawing fluid while cylinders A and D are neither drawing or exhausting fluid. From $90+\alpha$ to $180-\alpha$ degrees cylinders A and B exhaust fluid under pressure while cylinders C and D are connected for fluid intake. From $180-\alpha$ to $180+\alpha$ degrees cylinder B exhausts fluid under pressure and cylinder D is connected for fluid intake while cylinders A and C are neither drawing or exhausting fluid. From $180+\alpha$ to $270-\alpha$ degrees cylinders B and C are both exhausting fluid under pressure while cylinders A and D are both connected for fluid intake. From $270-\alpha$ to $270+\alpha$ degrees cylinder C is exhausting fluid under pressure and cylinder A is drawing fluid while cylinders B and D are neither drawing or discharging fluid. From $270+\alpha$ to $360-\alpha$ degrees cylinders C and D are both discharging fluid under pressure while cylinders A and B are connected for fluid intake. And from $360-\alpha$ to 360 (0°) degrees cylinder D is exhausting fluid under pressure and cylinder B is drawing fluid while cylinders A and C are neither connected for fluid intake or exhausting fluid under pressure.

From the operation of the pumping unit of this invention it becomes readily apparent that the factors governing the angle α are, for example, the distance between the lands 62 and 63 (piston 47 of cylinder B) forming the circumferential groove 59 and the distance between the ports 75 and 79. Also the position of the circumferential groove 59 of the piston 47 must be equidistant from each of the ports 75 and 79 when the piston 47 is at its mid-stroke position. From an examination of Figure 4 it is seen that it is advantageous from an operating viewpoint to construct the pump unit of this invention having the angle α as small as possible. However, as previously mentioned, it has been found that a pump unit of this invention constructed having the angle α equal to 18° operated quite satisfactorily.

Having thus described a preferred embodiment of the invention, it can now be seen that the objects of the invention have been fully achieved and it must be understood that changes and modifications may be made which do not depart from the spirit of the invention nor from the scope thereof as defined in the appended claims.

I claim:

1. A positive displacement liquid pump unit comprising a block member having a crankcase disposed in the central portion thereof, a longitudinally disposed drive shaft extending into said crankcase and journaled for rotation in said block member, a crank disposed in said crankcase in driven relation to said shaft, a cam disposed in said crankcase, said crank being journaled for rotation with respect to said cam, a first bore disposed transversely in said block member, the axis of said first bore being positioned perpendicular to the axis of said drive shaft, said first bore being closed at its outer end and its inner end opening into said crankcase, a first piston slidably disposed in said first bore, a first chamber formed by said first piston and the outer end portion of said first bore, the inner end of said first piston being in abutting relation with said cam, a first spring disposed in said first bore, said first spring being positioned to urge said first piston into abutting relation with said cam, a first fluid pressure compressible element disposed in the outer end portion of said first piston and in communicative relation with said first chamber, a first circumferential groove disposed on the central peripheral portion of said first piston, a second bore disposed transversely in said block member, the axis of said second bore being positioned perpendicular to the axis of said drive shaft and perpendicular to the axis of said first bore, said second bore being closed at its outer end and its inner end opening into said crankcase, a second piston slidably disposed in said second bore, a second chamber formed by said second piston and the outer end portion of said second bore, the inner end of said second piston being in abutting relation with said cam, a second spring disposed in said second bore, said second spring being positioned to urge said second piston into abutting relation with said cam, a second fluid pressure compressible element disposed in the outer end portion of said second piston and in communicative relation with said second chamber, a second circumferential groove disposed on the central peripheral portion of said second piston, a third bore disposed transversely in said block member, the axis of said third bore being positioned in alignment with the axis of said first bore, said third bore being closed at its outer end and its inner end opening into said crankcase, a third piston slidably disposed in said third bore, a third chamber formed by said third piston and the outer end portion of said third bore, the inner end of said third piston being in abutting relation with said cam, a third spring disposed in said third bore, said third spring being positioned to urge said third piston into abutting relation with said cam, a third fluid pressure compressible element disposed in the outer end portion of said third piston and in communicative relation with said third chamber, a third circumferential groove disposed in the central peripheral position of said third piston, a fourth bore disposed transversely in said block member, the axis of said fourth bore being positioned in alignment with the axis of said second bore, said fourth bore being closed at its outer end and its inner end opening into said crankcase, a fourth piston slidably disposed in said fourth bore, a fourth chamber formed by said fourth piston and the outer end portion of said fourth bore, the inner end of said fourth piston being in abutting relation with said cam, a fourth spring disposed in said fourth bore, said fourth spring being positioned to urge said fourth piston into abutting relation with said cam, a fourth fluid pressure compressible element disposed in the outer end portion of said fourth piston and in communicative relation with said fourth chamber, a fourth circumferential groove disposed in the central portion of said fourth piston, a first passage disposed in said block member, a plurality of first ports disposed in said block member, said first ports being positioned to connect communicatively the outer portion of each

of said bores with said first passage, a second passage disposed in said block member, a plurality of second ports disposed in said block member, said second ports being positioned to connect communicatively the inner portion of each of said bores with said second passage, said circumferential grooves being positioned on said pistons for registerable communication alternately with said first and second ports, each of said circumferential grooves being incapable of simultaneous registration of said first ports with said second ports, a first conduit disposed in said block member communicatively connecting said first chamber with said second circumferential groove, a second conduit disposed in said block member communicatively connecting said second chamber with said third circumferential groove, a third conduit disposed in said block member communicatively connecting said third chamber with said fourth circumferential groove, a fourth conduit disposed in said block member communicatively connecting said fourth chamber with said first circumferential groove, said fluid compressible elements being yieldable under influence of fluid pressure surges arising in said chambers during alternating of registration of said circumferential grooves with said first and second ports, said cam being arranged to maintain said second piston in one-quarter cycle phased relation in one direction with reference to said first piston, said cam being arranged to maintain said third piston in one-quarter cycle phased relation in one direction with reference to said second piston, said cam being arranged to maintain said fourth piston in one-quarter cycle phased relation in one direction with reference to said third piston, said cam being arranged to maintain said first piston in one-quarter cycle phased relation in one direction with reference to said fourth piston, and drive means connected to said shaft for rotating said shaft to actuate reciprocation of said pistons in balanced cyclic multi-phased relation whereby fluid enters through one of said passages to at least one of said chambers through at least one of said conduits and at least one of said circumferential grooves and subsequently discharged from said chambers through said conduits and said circumferential grooves in reversed direction into the other of said passages.

2. A positive displacement pump unit comprising a plurality of cylinders having pistons reciprocally disposed therein, a first passage means disposed in said unit, a first port disposed in said unit communicatively connected to one end portion of each of said cylinder and said first passage means, a second passage means disposed in said unit, a second port disposed in said unit communicatively connected to the other end portion of each of said cylinders and said second passage means, a chamber positioned at one end of each of said cylinders, a plurality of fluid pressure compressible elements disposed in the outer portions of said cylinders, at least one of said compressible elements being communicatively connected with the chamber of each of said cylinders, valve means disposed in the intermediate portion of each of said cylinders, a plurality of conduits disposed adjacent to said cylinders in said unit, each of said conduits being positioned to communicatively connect the chamber of one of said cylinders with the valve means of another of said cylinders, each of said valve means being positioned operatively to communicate one of said connected conduits alternately with each of said passage means, each of said valve means being incapable of communicating said first passage means with said second passage means, said compressible elements being yieldable under influence of fluid pressure surges arising in said chambers during operation of said valve means in said cylinders, and drive means for reciprocating said pistons in balanced cyclic multi-phased relation with each other whereby fluid enters through one of said passage means to at least one of said valve means and to at least one of said chambers through at least

9

one of said conduits and subsequently discharged from said chambers through said conduits and valve means in reversed direction into the other of said passage means.

3. A positive displacement liquid pump unit comprising a block member having a crankcase disposed in the central portion thereof, a longitudinally disposed drive shaft extending into said crankcase and journaled for rotation in said block member, a crank disposed in said crankcase in driven relation to said shaft, a cam disposed in said crankcase, said crank being journaled for rotation with respect to said cam, a first bore disposed transversely in said block member, the axis of said first bore being positioned perpendicular to the axis of said drive shaft, said first bore being closed at its outer end and its inner end opening into said crankcase, a first piston slidably disposed in said first bore, a first chamber formed by said first piston and the outer end portion of said first bore, a first spring disposed in said first bore, said first spring being positioned to urge the inner end of said first piston into abutting relation with said cam, a first fluid pressure compressible element disposed in said block member in communicative relation with said first chamber, a first circumferential groove disposed on the central peripheral portion of said first piston, a second bore disposed transversely in said block member, the axis of said second bore being positioned perpendicular to the axis of said drive shaft and perpendicular to the axis of said first bore, said second bore being closed at its outer end and its inner end opening into said crankcase, a second piston slidably disposed in said second bore, a second chamber formed by said second piston and the outer end portion of said second bore, a second spring disposed in said second bore, said second spring being positioned to urge the inner end of said second piston into abutting relation with said cam, a second fluid pressure compressible element disposed in said block member in communicative relation with said second chamber, a second circumferential groove disposed in the central peripheral portion of said second piston, a third bore disposed transversely in said block member, the axis of said third bore being positioned in alignment with the axis of said first bore, said third bore being closed at its outer end and its inner end opening into said crankcase, a third piston slidably disposed in said third bore, a third chamber formed by said third piston and the outer end portion of said third bore, a third spring disposed in said third bore, said third spring being positioned to urge the inner end of said third piston into abutting relation with said cam, a third fluid pressure compressible element disposed in said block member in communicative relation with said third chamber, a third circumferential groove disposed in the central peripheral portion of said third piston, a fourth bore disposed transversely in said block member, the axis of said fourth bore being positioned in alignment with the axis of said second bore, said fourth bore being closed at its outer end and its inner end opening into said crankcase, a fourth piston slidably disposed in said fourth bore, a fourth chamber formed by said fourth piston and the outer end portion of said fourth bore, a fourth spring disposed in said fourth bore, said fourth spring being positioned to urge the inner end of said fourth piston into abutting relation with said cam, a fourth fluid pressure compressible element disposed in said block member in communicative relation with said fourth chamber, a fourth circumferential groove disposed in the central peripheral portion of said fourth piston, a first passage disposed in said block member, a plurality of first ports disposed in said block member, said first ports being positioned to connect communicatively the outer portion of each of said bores with said first passage, a second passage disposed in said block member, a plurality of second ports disposed in said block member, said second ports being positioned to connect communicatively the inner portion of each of said bores with said second passage, said circumferential

10

grooves being positioned on said pistons for registerable communication alternately with said first and second ports, each of said circumferential grooves being incapable of simultaneous registration of said first ports with said second ports, a first conduit communicatively connecting said first chamber with said second circumferential groove, a second conduit communicatively connecting said second chamber with said third circumferential groove, a third conduit communicatively connecting said third chamber with said fourth circumferential groove, a fourth conduit communicatively connecting said fourth chamber with said first circumferential groove, said fluid compressible elements being yieldable under influence of fluid pressure surges arising in said chambers during alternating of registration of said circumferential grooves with said first and second ports, said cam being arranged to maintain said second piston in one-quarter cycle phased relation in one direction with reference to said first piston, said cam being arranged to maintain said third piston in one-quarter cycle phased relation in one direction with reference to said second piston, said cam being arranged to maintain said fourth piston in one-quarter cycle phased relation in one direction with reference to said third piston, said cam being arranged to maintain said first piston in one-quarter cycle phased relation in one direction with reference to said fourth piston, and drive means connected to said shaft for rotating said shaft to actuate reciprocation of said pistons in balanced cyclic-multi-phased relation whereby fluid enters through one of said passages to at least one of said chambers through at least one of said conduits and at least one of said circumferential grooves and subsequently discharged from said chambers through said conduits and said circumferential grooves in reversed direction into the other of said passages.

4. A positive displacement liquid pump unit comprising a block member having a crankcase disposed in the central portion thereof, a longitudinally disposed drive shaft extending into said crankcase and journaled for rotation in said block member, a crank disposed in said crankcase in driven relation to said shaft, a cam disposed in said crankcase, said crank being journaled for rotation with respect to said cam, a first bore disposed transversely in said block member, the axis of said first bore being positioned perpendicular to the axis of said drive shaft, said first bore being closed at its outer end and its inner end opening into said crankcase, a first piston slidably disposed in said first bore, a first chamber formed by said first piston and the outer end portion of said first bore, a first fluid pressure compressible element disposed in said unit and positioned in communicative relation with said first chamber, a first circumferential groove disposed on the central peripheral portion of said first piston, a second bore disposed transversely in said block member, the axis of said second bore being positioned perpendicular to the axis of said drive shaft and perpendicular to the axis of said first bore, said second bore being closed at its outer end and its inner end opening into said crankcase, a second piston slidably disposed in said second bore, a second chamber formed by said second piston and the outer end portion of said second bore, a second fluid pressure compressible element disposed in said unit and positioned in communicative relation with said second chamber, a second circumferential groove disposed in the central peripheral portion of said second piston, a third bore disposed transversely in said block member, the axis of said third bore being positioned in alignment with the axis of said first bore, said third bore being closed at its outer end and its inner end opening into said crankcase, a third piston slidably disposed in said third bore, a third chamber formed by said third piston and the outer end portion of said third bore, a third fluid pressure compressible element disposed in said unit and positioned in communicative relation with said third chamber, a third circumferential groove disposed

in the central peripheral portion of said third piston, a fourth bore disposed transversely in said block member, the axis of said fourth bore being positioned in alignment with the axis of said second bore, said fourth bore being closed at its outer end and its inner end opening into said crankcase, a fourth piston slidably disposed in said fourth bore, a fourth chamber formed by said fourth piston and the outer end portion of said fourth bore, a fourth fluid pressure compressible element disposed in said unit and positioned in communicative relation with said fourth chamber, a fourth circumferential groove disposed in the central peripheral portion of said fourth piston, means for connecting the inner ends of said pistons with said cam in engaging relation, a first passage disposed in said block member, a plurality of first ports disposed in said block member, said first ports being positioned to connect communicatively the outer portion of each of said bores with said first passage, a second passage disposed in said block member, a plurality of second ports disposed in said block member, said second ports being positioned to connect communicatively the inner portion of each of said bores with said second passage, said circumferential grooves being positioned on said pistons for registerable communication alternately with said first and second ports, each of said circumferential grooves being incapable of simultaneous registration of said first ports with said second ports, a first conduit communicatively connecting said first chamber with said second circumferential groove, a second conduit communicatively connecting said second chamber with said third circumferential groove, a third conduit communicatively connecting said third chamber with said fourth circumferential groove, a fourth conduit communicatively connecting said fourth chamber with said first circumferential groove, said fluid compressible elements being yieldable under influence of fluid pressure surges arising in said chambers during alternating of registration of said circumferential grooves with said first and second ports, said cam being arranged to move said second piston in one-quarter cycle phased relation in one direction with reference to said first piston, said cam being arranged to move said third piston in one-quarter cycle phased relation in one direction with reference to said second piston, said cam being arranged to move said fourth piston in one-quarter cycle phased relation in one direction with reference to said third piston, said cam being arranged to move said first piston in one-quarter cycle phased relation in one direction with reference to said fourth piston, and drive means connected to said shaft for rotating said shaft to actuate reciprocation of said pistons in balanced cyclic multi-phased relation whereby fluid enters through one of said passages to at least one of said chambers through at least one of said conduits and at least one of said circumferential grooves and subsequently discharged from said chambers through said conduits and said circumferential grooves in reversed direction into the other of said passages.

5. A positive displacement liquid pump unit comprising a block member having a crankcase disposed therein, a longitudinally disposed crankshaft extending into said crankcase and journaled for rotation in said block member, cam means mounted on and journaled for rotation with respect to said crankshaft, a first bore disposed transversely in said block member, the axis of said first bore being positioned perpendicular to the axis of said crankshaft, said first bore being closed at its outer end and its inner end opening into said crankcase, a first piston slidably disposed in said first bore, a first chamber formed by said first piston and the outer end portion of said first bore, a first fluid pressure compressible element disposed in said unit and positioned in communicative relation with said first chamber, a first circumferential groove disposed on the central peripheral portion of said first piston, a second bore disposed transversely in said

block member, the axis of said second bore being positioned perpendicular to the axis of said crankshaft, said second bore being closed at its outer end and its inner end opening into said crankcase, a second piston slidably disposed in said second bore, a second chamber formed by said second piston and the outer end portion of said second bore, a second fluid pressure compressible element disposed in said unit and positioned in communicative relation with said second chamber, a second circumferential groove disposed in the central peripheral portion of said second piston, a third bore disposed transversely in said block member, the axis of said third bore being positioned perpendicular to the axis of said crankshaft, said third bore being closed at its outer end and its inner end opening into said crankcase, a third piston slidably disposed in said third bore, a third chamber formed by said third piston and the outer end portion of said third bore, a third fluid pressure compressible element disposed in said unit and positioned in communicative relation with said third chamber, a third circumferential groove disposed in the central peripheral portion of said third piston, a fourth bore disposed transversely in said block member, the axis of said fourth bore being positioned perpendicular to the axis of said crankshaft, said fourth bore being closed at its outer end and its inner end opening into said crankcase, a fourth piston slidably disposed in said fourth bore, a fourth chamber formed by said fourth piston and the outer end portion of said fourth bore, a fourth fluid pressure compressible element disposed in said unit and positioned in communicative relation with said fourth chamber, a fourth circumferential groove disposed in the central peripheral position of said fourth piston, a first passage means disposed in said unit, said first passage means being communicatively connected to the outer portion of each of said bores, a second passage means disposed in said unit, said second passage means being communicatively connected to the inner portion of each of said bores, said circumferential grooves being positioned on said pistons for registerable communication alternately with each of said passage means, each of said circumferential grooves being incapable of communicating said first passage means with said second passage means, a first conduit communicatively connecting said first chamber with said second circumferential groove, a second conduit communicatively connecting said second chamber with said third circumferential groove, a third conduit communicatively connecting said third chamber with said fourth circumferential groove, a fourth conduit communicatively connecting said fourth chamber with said first circumferential groove, said fluid compressible elements being yieldable under influence of fluid pressure surges arising in said chambers during alternating of registration of said circumferential grooves with each of said passage means, said cam means being arranged to move said second piston in one-quarter cycle phased relation in one direction with reference to said first piston, said cam means being arranged to move said third piston in one-quarter cycle phased relation in one direction with reference to said second piston, said cam means being arranged to move said fourth piston in one-quarter cycle multi-phased relation in one direction with reference to said third piston, said cam means being arranged to move said first piston in one-quarter cycle phased relation in one direction with reference to said fourth piston means disposed in said block member for connecting the inner ends of said pistons in driven relation with said cam means, and drive means connected to said crankshaft for rotating said crankshaft to actuate reciprocation of said pistons in balanced cyclic phased relation whereby fluid enters through one of said passage means to at least one of said chambers through at least one of said conduits and at least one of said circumferential grooves and subsequently discharged from said chambers through said conduits and

said circumferential grooves in reversed direction into the other of said passage means.

6. A positive displacement liquid pump unit comprising a block member having a crankcase disposed therein, a longitudinally disposed crankshaft extending into said crankcase and journaled for rotation in said block member, cam means mounted on and journaled for rotation with respect to said crankshaft, four cylinders having reciprocable pistons disposed in said block member, the axes of said cylinders being positioned perpendicular to the axis of said crankshaft, the outer end of each of said cylinders being closed and the inner ends opening into said crankcase, resilient means disposed in said cylinders positioned to urge one end of each of said pistons in abutting relation with said cam means, said cam means being arranged to reciprocate said pistons in balanced cyclic phased relation with each other, valve means operatively responsive to movement of said pistons disposed in the intermediate portion of each of said cylinders, a first passage means disposed in said unit, said first passage means being communicatively connected to one end portion of each of said cylinders, a second passage means disposed in said unit, said second passage means being communicatively connected to the other end portion of each of said cylinders, a plurality of conduits disposed adjacent to said cylinders, each of said conduits being positioned to communicatively connect the outer end of one cylinder with the valve means of another cylinder having its piston displaced in one direction one-quarter cycle from the piston of said one cylinder, a plurality of fluid pressure compressible elements disposed in said pump, at least one of said fluid pressure compressible elements being in communicative relation with each of said conduits, each of said valve means being operatively arranged to communicate alternately each of said passage means with its associated conduit, each of said valve means being incapable of communicating said first passage means with said second passage means, a plurality of fluid pressure compressible elements disposed in said pump, said elements being yieldable under influence of fluid pressure, one of said elements being connected in fluid communication with the outer end of said cylinders, and drive means connected to said crankshaft for reciprocating said pistons in said cylinders whereby fluid enters through one of said

passage means intermittently into each of said cylinders moving in balanced multi-phased relation with respect to each other and subsequently discharging said fluid under pressure into the other of said passage means.

7. A positive displacement liquid pump unit comprising four cylinders each having a piston reciprocally disposed therein, said cylinders each having valve means disposed therein, said valve means being operatively responsive to movement of said pistons, a first passage means disposed in said unit communicatively connected to said valve means of each of said cylinders, a second passage means disposed in said unit communicatively connected to said valve means of each of said cylinders, a plurality of conduits disposed adjacent said cylinders, one of said conduits being positioned adjacent each of said cylinders, each said conduit positioned to connect communicatively the outer end of one cylinder with the valve means of another cylinder, a plurality of fluid pressure compressible elements, at least one of said elements being in communicative relation with each of said conduits, each of said valve means being arranged to connect communicatively one of said conduits alternately with each of said passage means, each of said valve means being incapable of communicating said first passage means with said second passage means, said compressible elements being yieldable under influence of fluid pressure surges arising in said conduits from actuation of said pistons during movement of said valve means, and means for reciprocally moving said pistons in balanced multi-phased relation whereby fluid enters through one of said passage means into said cylinders and subsequently discharged through the other of said passage means.

References Cited in the file of this patent

UNITED STATES PATENTS

1,719,693	Ernst	July 2, 1929
1,893,825	Ernst	Jan. 10, 1933
2,427,253	Browne	Sept. 9, 1947
2,636,349	Schnell	Apr. 28, 1953
2,774,619	Mercier	Dec. 18, 1956

FOREIGN PATENTS

888,206	Germany	July 16, 1953
---------	---------	---------------