

July 27, 1954

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2,684,630

VARIABLE DELIVERY FORCE PUMP

Filed Nov. 20, 1951

*Fig. 1.*

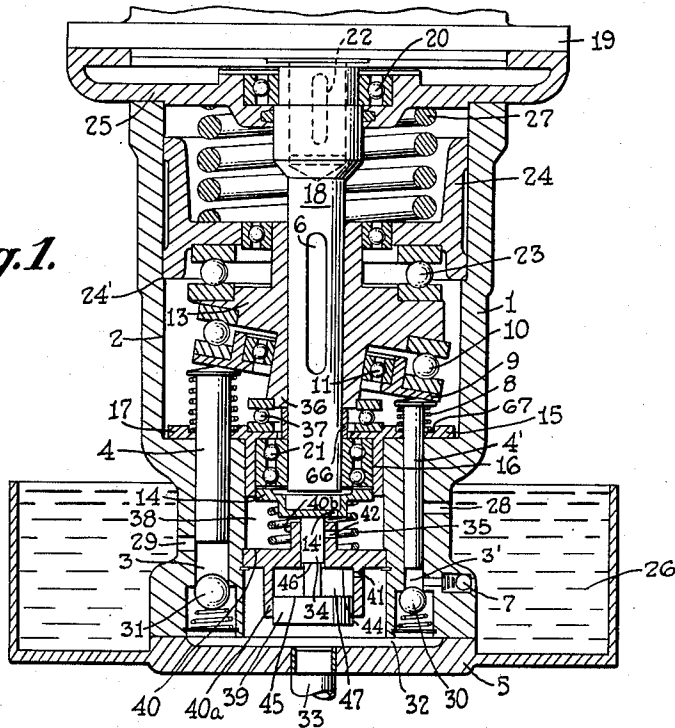


*Fig. 2.*

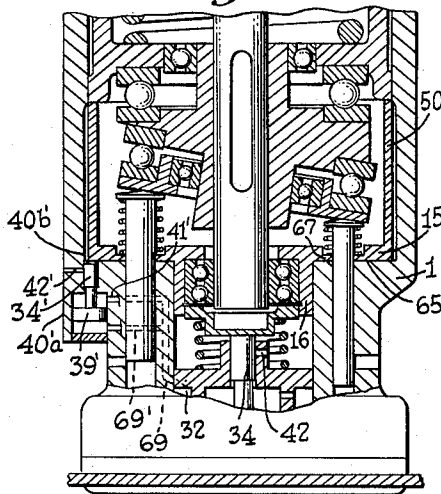


*Fig. 3.*

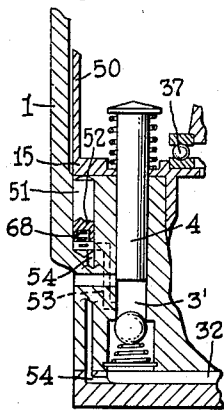
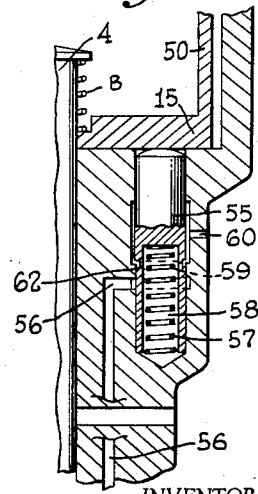


*Fig. 4.*



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## UNITED STATES PATENT OFFICE

2,684,630

## VARIABLE DELIVERY FORCE PUMP

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Application November 20, 1951, Serial No. 257,278

Claims priority, application Switzerland  
November 29, 1950

19 Claims. (Cl. 103—37)

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This invention relates to a variable delivery force pump having a plurality of plungers driven by a single swash plate of constant inclination in which, by axial displacement of both the plurality of plungers and the swash plate relative the pump drive shaft, the effective throw of the plungers is varied.

An object of the instant invention is to provide control means for automatically and under the pressure of the liquid being pumped to axially displace both the swash plate and the plurality of pumping plungers of variable delivery force pumps.

A further object of the invention is to decrease automatically the delivery of the pump on increased delivery pressure and automatically to increase the delivery of the pump on decreased delivery pressure without any substantial loss in pump efficiency.

Still a further object of the invention is to provide a variable delivery pump control means in which the resultant force of the control means for automatically varying the throw of the delivery plungers is always substantially coaxial with the pump drive shaft for all displacements of the rotatable swash plate axially the drive shaft.

The foregoing, and other obvious, objects of the instant invention are accomplished by providing a control means coaxial with the pump drive shaft, and in modified embodiments a plurality of auxiliary control means symmetrically disposed with respect to the pump drive shaft, responsive to pressure prevailing in a compartment to which the pumping plungers deliver the pumped liquid, the control means displacing a swash plate of constant inclination to the drive shaft from a minimum displacement, corresponding broadly to the maximum delivery of the pumping plungers, to a predetermined maximum displacement, corresponding broadly to the minimum delivery of the pumping plungers, with preferably a sudden and relative instantaneous displacement of the swash plate from a predetermined intermediate displacement to the maximum displacement thereof.

The invention is more completely described in the following specification with reference to the drawings which disclose illustrative embodiments thereof and in which:

Figure 1 is a vertical section through a first illustrative embodiment of a variable delivery pump with vertically positioned pumping plungers having one control means axially positioned relative to the drive shaft of the pump;

Figure 2 is a vertical partial section through a

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modified illustrative embodiment incorporating in addition to the axial control means of the embodiment of Figure 1 one or more auxiliary control means non-axially disposed with respect to the drive shaft; and

Figures 3 and 4 are vertical partial sections of illustrative modified auxiliary non-axial control means.

While the pump housing 1, together with its main bore 2, and its plunger bores, 3 and 3', is shown in the drawings with the principal pump axis 6 in vertical position, the pump may be in other spatial positions, for example horizontal. The plurality of plunger bores, 3 and 3', for example twelve, are disposed circularly about the axis 6 in the lower end of housing 1 in the region of the reduced portion 2' of the main bore and each has its axis parallel to the pump axis 6. In the illustrative embodiment bores 3 are for delivery plungers 4 of a relatively large diameter and bores 3' for plungers 4' of smaller diameter, and may be arranged alternately a larger and a smaller bore or in groups of the same size circumferentially and with each bore axis substantially equidistant from its adjacent bore axes. The number of larger diameter plungers may differ from the number of the smaller diameter plungers, that is for the stated number of twelve, need not be six each. Thus there may be employed eight or nine larger diameter plungers, the others being smaller diameter plungers of which each is positioned in the pump housing about the main bore between successive groups of the larger diameter plungers. The bores and plungers, while shown as of two different sizes of diameter and cross section in the embodiment of Figure 1 may, however, be of the same diameter and cross section. The pump housing is disposed either as shown in Figure 1 in a reservoir 5 of the liquid to be pumped so that the liquid inlet bores are at all times below the surface of the reservoir liquid, with the upper pump portion extending out of the reservoir, or in a reservoir completely surrounding the pump housing with all of the housing immersed in the reservoir liquid, as for example when the principal pump axis is horizontal (not shown).

Each of the plungers 4 and 4' is pressed at its upper head end by means of a coiled spring 2 against a carrier ring 9 supported axially and radially against a swash plate 13 by roller bearings 10 and 11 respectively. Swash plate 13, having a constant angular inclination, is supported on the pump drive shaft 18 positioned with its axis coincident substantially with the principal

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axis 6, and rotates with the shaft but is axially displaceable on the shaft. The lower end of each spring is seated in a recess 67 in a flange ring 15 integral with a bushing 16 which is slidably fitted into the smaller portion 2' of the main housing bore so that the flange ring 15 rests, when the pump is at rest as shown in Figure 1, on the annular shoulder 17 of the main bore formed by the reduction of the main bore 2 to its smaller portion 2'. The drive shaft 18 is driven by a motor 19 positioned on the pump cover 25, the motor having a stub shaft extending into the upper end of shaft 18 and connected thereto by a key 22. The upper end of drive shaft 18 is journaled in the cover 25 by means of the bearing 20, while its lower end, which extends into bushing 16, is journaled in bushing 16 by means of a bearing 21. Through the roller bearing 23 the swash plate 13 is supported against the guide member 24 which is axially displaceable in the upper portion of the main bore 2 and is pressed downwardly by the pump main spring 27 braced between the guide member and the pump cover.

Each plunger bore, 3 and 3', is provided with a radial intake bore, 29 and 28, from the plunger bore to the exterior of the pump housing 1 and below the surface of the liquid 26 in the reservoir 5. The position of the radial bores 28 and 29 longitudinally of the principal pump axis 6, determines during what portions of the travel of the pumping plungers liquid to be pumped may flow from the reservoir into bores 3 and 3'. Bore 3' are additionally each provided with a suction valve 7 positioned axially at substantially the lowermost throw position of the plunger 4', in order that even when the radial bore 28, positioned upwardly from valve 7, is still closed by the plunger 4', the latter will nevertheless draw liquid from reservoir into the bore 3'. Suction valves 7 of the bores 3' may however be omitted, in which event the radial bore 28 will also control the drawing of liquid into bore 3' in the same manner as radial bores 29 for plunger bores 3. Liquid 26 is drawn into the bores 3 and 3' from the reservoir during the suction strokes of plungers 4 and 4' and then, on the delivery strokes of the plungers, or more accurately that portion thereof during which the plungers close the respective radial intake bores, is forced through the respective spring pressed ball valves 30 and 31, positioned at the lower ends of the plunger bores, into the pump pressure chamber 32, from which it is conducted to the point of use by the delivery pipe 33.

It will be noted from Figure 1, which shows the pump at rest, that the axial distance between the bottom of cover 25 and the top of guide member 24, which is pressed by main spring 27 against a shoulder 24' limiting its downward movement, is such that with the guide member moved axially upward its maximum against the pressure of the main spring, the most upwardly positioned of the radial intake ports, 28 in Figure 1, will be opened by its plunger. Preferably also such distance is such that with the guide so displaced to its uppermost position, and hence also the swash plate 13 under the influence of the delivery plungers and their spring 8, the heads of the plungers will still be in contact with the ring 9, thereby eliminating shock impacts and excessive wear attendant thereupon. Ring 9 may nevertheless be omitted and the plunger heads made to bear directly on the swash plate, but the ring 9 is preferred so that it, rather than the

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swash plate, need only be replaced in the event of undue wear.

Below the lower bearing 21 in which the lower end of the drive shaft 18 is journaled in bushing 16, a disc 14 is affixed to the bushing 16 and serves as the upper seat of a spring 35, which spring is of such configuration and magnitude that it exerts a greater force upwardly on disc 14 and hence bushing 16 and its integral flange ring 15 than the force of all the springs 8 exert downwardly on the ring 15 in the rest position of the pump. The lower hub end of the swash plate 13 is supported axially on the ring 15 and bushing 16 by a roller bearing 37, so that the swash plate 13, the bearing 37, the ring 15 and the bushing 16 are tensioned constantly, and thus move as a unit upwardly and downwardly axially on the drive shaft 18.

The lower end of the spring 35 bears against a plate 40 extending across and fixed in the reduced portion 2' of the main bore and at some distance axially below the disc 14. Plate 40 has integral therewith on its lower face a cylinder 40a and integral with its upper face a second cylinder 40b having a substantially smaller internal diameter than has the cylinder 40a. Each of the cylinders 40a and 40b is coaxial with the driving shaft 18, while the plate 40 forms the upper or cover wall of the pump pressure chamber 32. A mushroom type valve 34 bears with its upper end against the disc 14 and extends downwardly through the coaxial cylinders 40a and 40b. The stem of valve 34 is of such length that only the lower face of its enlarged head 39 is permitted to extend, by means of a stop or other known means, in the position of minimum axial displacement of the swash plate and with the upper end of valve 34 bearing against the disc 14, out of the lower end of cylinder 40a but with such lower face away from the bottom of the pressure chamber 32. In the vertically positioned embodiment of the invention and as shown in Figure 1, the stem of valve 34 is preferably of smaller diameter at its head end than at its upper end, and the cylinder 40a is provided with a radial port 41 in the region of the cylinder toward the plate 40, that is in its upper end region, and the cylinder 40b with a radial port 42 at a predetermined distance axially upward from the plate. Port 41 is thus normally open, and connects the air containing compartment 47, formed by the lower face 44 of the plate 40, the upper face 45 of valve head 39 and the walls of cylinder 40a, by the pressure chamber 32, whereas port 42, normally closed by the unrecessed upper portion of the stem of valve 34, connects to the pressureless chamber 38 formed between the upper face of plate 40, the walls of the reduced portion 2' of the main pump bore, the lower face of disc 14 and the lower rim face of the bushing 16. The recessed portion of stem of valve 34 is of such length axially that when the upper end of the valve head 39 closes the radial port 41, the upper end of the recessed valve stem opens port 42. It is thus apparent that when the surface of valve head 39 comes to rest upon the lower face 44 of the plate 40, the maximum displacement of the swash plate 13 and all of the axially displaceable elements is fixed. The surfaces 44 and 45 are finished accurately to fit each other so that no, or substantially no, liquid leakage occurs when they are seated on each other.

The mode of operation is as follows: On rotation of the drive shaft 18, the swash plate 13 rotates therewith and the plungers 4 and 4' are in the po-

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sition shown in Figure 1, in respectively their lowest position of the start of the delivery stroke and the lowermost position of the start of the suction stroke, with radial bore 29 substantially completely unlocked by plunger 4 and liquid filling the bore 3 from the bore 29 to the closed ball valve 31, and the radial bore 28 closed, suction valve 7 closed and perhaps no liquid, or only a residue from the previous delivery stroke, in the bore 3' between the plunger 4' and the closed ball valve 30. As plunger 4 is depressed by the swash plate against the plunger's spring 8, the bore 29 is first sealed by the plunger in its downward path, the pressure of the plunger on the liquid in bore 3 is transmitted to ball valve 31 which opens, the plunger for the remainder of its downward throw, to the position shown in the dashed line across bore 3 in Figure 1, ejecting the confined liquid into the pressure chamber 32. While the plunger 4 is moving downwardly, plunger 4' under the action of its spring 8 moves upwardly for the suction stroke during all of which the suction valve 7 is open, ball valve 30 remaining closed, until the plunger 4' reaches the upper limit of its throw, shown by the dashed line across bore 3', during no part of which throw it will be noted is the bore 28 opened by the plunger with the swash plate 13 axially in its lowermost position shown in Figure 1. On continued rotation of the swash plate, plunger 4 moves through its entire suction stroke upwardly with ball valve 31 closed by its spring and the suction, with liquid flowing into the bore 3 only after the plunger has passed bore 29; and in the meantime, plunger 4' travels downwardly on its delivery stroke, valve 7 closing on commencement of the delivery stroke and ball valve 30 opening at such time and remaining open for the whole of the delivery stroke so that plunger 4' ejects the liquid confined in bore 3' into the pressure chamber. Assume now that liquid, as the result of not being drawn off quickly enough by pipe 33 to the point of use, commences to accumulate in the pressure chamber. As the level of the liquid under pressure in the pressure chamber rises, valve head 39 is forced upwardly in cylinder 40a. As before stated, this will force the entire axially displaceable assembly of elements, including valve 34, disc 14, bushing 16, ring 15, swash plate 13 and guide member 24, together with the intervening plunger springs 8 and the various bearings, upwardly against main pump spring 27. The plungers 4 and 4' are thus also moved upwardly in their bores with the obvious result that at least the effective delivery stroke of plungers 4 is decreased, since when displaced upwardly the plungers 4 in the initial position of their delivery stroke will leave their bores 29 open for re-expulsion therethrough of the liquid drawn in on the suction stroke. As is obvious from the drawing, the residual portion of the delivery stroke during which confined liquid in bores 3 is ejected into the pressure chamber 32, is the less the higher the swash plate is displaced axially. In fact, the residual portion of the delivery stroke may be made substantially zero providing the maximum upward displacement of the swash plate is properly predetermined, so that no liquid is effectively pumped or delivered to the pressure chamber by the plungers 4. With the swash plate displaced axially upward to an extent that at no time the plungers 4' open their respective ports 28, the liquid delivered by plungers 4' to the pressure chamber remains substantially unchanged from that delivered with the swash plate in its

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lowest, or minimum, axial position. However, when the swash plate is displaced axially that the plungers 4' in their strokes do uncover the respective bores 28, the liquid delivered thereby is decreased in similar fashion substantially as for the plungers 4.

The displacement of the valve head 39 upwardly is not the only force which tends to move the axially displaceable elements upwardly. As the back pressure on the plungers 4 and 4' delivering liquid increases, the total sum of such pressures also tends to compress the main spring 27, by way of the springs 8, and thus aids in varying the total delivery. Thus if the pressure which the plungers have to overcome is large, main spring 27 is increasingly compressed and, as a result of the smaller effective throw of the plungers 4, and, at a predetermined point, also of the plungers 4' in bores 3' provided with the suction valves 7, less liquid is delivered to the pressure chamber, and vice versa. Thus without loss in efficiency, the liquid pumped and delivered is automatically decreased on increased delivery pressure and increased on decreased delivery pressure.

The pressure within the pressure chamber thus may rise to a predetermined maximum amount, and since the ports 41 and 42 are at such predetermined locations relative to each other that the upward movement of the valve head closes port 41 while simultaneously the recessed portion of the stem of valve 34 opens port 42, such maximum hydraulic pressure forces the valve head 39 quickly upward until the upper surface 45 of the valve head rests firmly against the lower surface 44 of plate 40. Thus the swash plate is axially displaced against the pressure of the main spring 27 to its uppermost and maximum position, and on continuous rotation while still actuating the plungers 4 and 4' has reduced the effective delivery throw of both to substantially zero. It will be noted that by positioning the ports 41 and 42 at predetermined greater or lesser distances from the surfaces of the fixed plate 40, and where required increasing or decreasing the length of the recessed portion of the stem of valve 34, the position at which the sudden upward movement of the entire axially displaceable assembly occurs, may be predetermined. For the eventuality that pumped liquid may leak into the compartment 47 from the pressure chamber 32 while port 41 is open, which leakage fluid on closure of port 41 will be ejected around the recessed portion of the stem of valve 34 on further upward movement of the valve head 39 through the port 42 into the relatively pressureless chamber 33, a small outlet opening 14' is provided in the disc 14, by way of which liquid accumulated in sufficient quantity in the pressureless chamber 33 may be drawn off and returned to the reservoir. It will be noted, however, that notwithstanding accumulation of any such leakage liquid in the pressureless chamber, the pump will continue to operate. Thus, even if the accumulated liquid in the pressureless chamber 33 should be above the level of disc 14 in its lowermost position, namely the position of Figure 1, the displaceable combination will not be markedly impeded in its downward movement toward such lowermost position by such accumulated leakage liquid which will in part pass through the opening 14' and in part, while bore 42 is open, drain back to the compartment 47 and drain therefrom through port 41 back into the pressure chamber 32 when the port 41 is being opened by valve head 39 until such time as the upper

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face 45 of the valve head is below the lower edge of open port 41. If desired, the port 41 and 42 may be eliminated, in which event there is no sudden upward movement of the displaceable combination, only a continuous gradual upward movement until surface 45 of the valve head 39 comes to rest against the surface 44 of the plate 40.

The embodiment of the invention shown in Figure 2 includes all the elements of the embodiment of Figure 1 except the bearing 37 positioned between the lower hub of the swash plate and the flange ring 15 integral with bushing 16. As a substitute for such bearing and to transmit the axial movement of the ring 15 directly to the guide member 24, flange ring 15 has affixed thereto and preferably integral therewith, a hollow cylindrical collar 50 fitting into the main bore 2 and of a height such that its upper rim abuts the lower rim of guide member 24. In this embodiment then, the pressure of the control valve 34 is transmitted from the disc 14, bushing 16, integral flange ring 15, and hollow collar 50 directly to the guide member, saving wear on the axial bearing 23 between the upper face of the swash plate and the guide member. In addition the embodiment of Figure 2 has two or more laterally positioned auxiliary control valves 34' (one is shown in the figure) to produce a sudden conversion of the axial displacement from one which increases uniformly with increasing pressure to one which, as the predetermined pressure of the liquid within the pressure chamber 32 corresponds to the predetermined displacement below maximum displacement, substantially instantly passes from the predetermined displacement to the maximum displacement. The auxiliary control valves 34' are disposed symmetrically about the principal pump axis 6 in individual bores in the pump housing so that the resultant of the forces they apply to the flange ring 15 lies on the principal axis 6 together with that of the axially central control valve 34. Auxiliary control valves 34' and the bores in which they operate are respectively of construction and form similar to the control valve 34 and the cylinders 40a and 40b, with their enlarged heads 39' on and in contact with bores 40a' and the stems of valve 34' in bores 40b', the non-head ends of the valves 34' bearing against the annular flange 15. The radial port 42' of each bore 40b' is above the surface of the liquid 26 in reservoir 5, that is, opens to the external atmosphere. The radial port 41', opening into the portion of bore 40a' between valve head 39' and bore 40b', is connected by way of a channel 69 to the pressure compartment 32, the channel also being connected to a radial bore 69' which opens into the portion of the bores 40a' below the valve head 39'. Liquid under pressure is thus suppleable by channel 69 and radial bore 69' to below the valve head 39' and when supplied forces the head upwardly even though some liquid under pressure may flow through the radial bore 41' into the portion of bore 40a' above the head 39' since the upper surface of the head 39' is less (by the area of the stem) than the lower surface of the head acted on by the liquid pressure. With increasing liquid pressure the valve head is slowly moved upwardly by the resultant force and the bore 41' is closed by head 39', and on such closure, the portion of lesser diameter of the valve stem 34' opens the bore 42', permitting the liquid above the head to be expelled therethrough on further upward move-

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ment of the head. This unimpeded expulsion of the liquid above the head causes the valve 34' to accelerate the speed of its motion in the direction of the maximum displacement of the annular flange 15. With decreasing liquid pressure in pressure chamber 32, and the consequent displacement of the valves toward the position of minimum displacement, the liquid below the valve head drains back into the pressure chamber.

In Figure 3 a modified form of auxiliary control valve means is shown. The auxiliary control valve of this embodiment is essentially a plunger 51 of uniform diameter its length provided in bores in the pump housing disposed symmetrically about the principal axis 6 as in the case of valves 34', with the upper ends 52 of plungers 51 acting directly on the annular flange 15 under the pressure of liquid from channel 54 connected to the pressure chamber 32 from the lower end of the bores housing the plungers 51. It is obvious that the plunger 51 is at all times under the same pressure as prevails in the pressure chamber. In a further modification of the auxiliary control valve means of the type employing plunger 51, the region of its housing bore below the plunger 51 may be connected to an adjacent liquid delivery plunger bore 3' rather than to the pressure chamber. This modification is also shown in Figure 3, where the channel 54, shown in dashed lines, connects such region of the plunger bore to the bore 3' of the delivery plunger 4' in the region of bore 3' below plunger 4', and a spring 68 presses from the bottom of the auxiliary plunger bore against plunger 51 forcing it at all times against annular flange 15, the channel 54 being eliminated in this modification. By means of channel 53 the auxiliary plunger 51 in this modification exerts an upward pressure against the annular flange 15 due to the effect of liquid pressure only during the delivery stroke of plunger 4', and spring 68 prevents plunger 51 from leaving the annular flange during the suction stroke of plunger 4'. In such modification, it will be noted that the bore 3' has itself been modified by the elimination of the suction valve 7 of Figure 1. A particularly advantageous application of the last described auxiliary plunger-type control means is given when the pump, as shown in the illustrative embodiment of Figure 1, has delivery plungers of two diameters respectively, each of the smaller diameter delivery plunger bores having a cooperating auxiliary control valve of this type, and the sum of the cross-sectional surfaces of the auxiliary control valves and the small diameter liquid delivery plungers is equal to the cross-sectional surface of the larger diameter liquid delivery plungers. In such case the pressure exerted by the auxiliary control valves and the delivery plungers of the two diameters on the main spring 27 is equal to that similarly exerted in a pump of which all the delivery plungers are of the larger of the two diameters.

The sudden quick displacement of the axially displaceable elements from the predetermined displacement to the maximum displacement may also be obtained by providing auxiliary control valves of the type of which one is shown in Figure 4. Auxiliary control valves 55 are disposed in the pump housing in the same manner and locations as are the auxiliary valves 34' of the embodiment of Figure 2 and valves 51 of the embodiment of Figure 3. Valve 55 is essentially a plunger having lower integral skirts of the

same diameter as the plunger, within the hollow skirt of which a spring 57 presses the plunger continuously against the annular flange 15, the total length of the valve and its integral skirt being such that in the position of minimum displacement shown in Figure 4, bore 59, or a plurality thereof through the outer cylindrical surface of the skirt, is at the bottom substantially of an enlarged portion of the bore 58, in the lower and upper unenlarged portions of which the valve 55 is a sliding fit. An exhaust bore 60 connects the enlarged portion of bore 58 to the external atmosphere, while somewhat below this enlarged portion the liquid channel 56 connects the bore 58 to the pressure chamber 32. In the position of minimum displacement, channel 56 is closed by the plunger skirt and, as shown in Figure 4, remains closed thereby until, on reaching a predetermined displacement, the skirt opens channel 56. Prior to the opening of channel 56, the plunger bore region below valve 55 was under no pressure, being connected to the external atmosphere through 58, 59 and 60. The position of the bore 59 through the wall of the plunger skirt from the free end of the skirt is such that with channel 56 opened, the lower edge 62 of the bore 59 will be above the upper edge 63 of the enlarged portion of bore 58. Hence the external connection through the bore 60 is now closed, and valve 55 now subjected to the same pressure as prevails in the pressure chamber. As the result of this suddenly applied additional force by the auxiliary control valves 55, for example two at diametrically opposite portions of annular flange 15, the hollow cylinder 50 forces the guide 24 almost instantly into its position of maximum displacement.

It will be readily apparent that various modifications in, and embodiments of, the variable delivery pump of the instant invention as disclosed by way of illustrative embodiments may be made without departing from the spirit of this invention. Some have previously been discussed and illustrated, others may include using the auxiliary control valves of any of Figures 2, 3 and 4 in selected groupings in a given pump some of one type and some of the other or both other types, or having the valve springs 8 bear directly against the main bore shoulder 17 by eliminating the spring recesses 67 in the annular flange 15 and substituting therefor larger openings in the flange which permit the plunger valve springs to pass through the flange without interference, or eliminating the axial bearing 37 even in pumps having no hollow collar 50 and substituting therefor a spacer shell 66 (see Figure 1) to transmit the pressure of control valve 34 from bearing 20 to swash plate 13, etc.

What we claim is:

1. A variable delivery force pump comprising a housing, a main bore substantially central and axial of the housing, a rotatable drive shaft substantially central of the main bore, a fixed plate transverse of the main bore and dividing the main bore into a first and a second compartment, the drive shaft extending through the first compartment toward but not sufficiently to engage the transverse plate, means including a swash plate rotatable with the shaft axially displaceable on the shaft, the swash plate having a predetermined inclination to the shaft, a plurality of secondary bores parallel to the drive shaft in the housing below the swash plate, a plunger reciprocable in each secondary bore, an inlet bore extending to a point external of the

housing for each secondary bore and adapted to be opened and closed by the respective plunger, spring means pressing each plunger against the swash plate, a main spring means pressing the means including the swash plate toward the transverse plate and against the plunger spring means, a liquid delivery bore connecting each secondary bore to the second compartment, and control means extending from the second compartment into the first compartment and bearing against the means including the swash plate to displace the latter means axially of the shaft against the main spring means in accordance with the pressure prevailing within the second compartment to vary the effective pressure stroke of the plungers.

2. A variable delivery force pump according to claim 1 in which the maximum possible displacement of the control means is not in excess of the axial projection of the inclination of the swash plate on the drive shaft.

3. A variable delivery force pump according to claim 1 in which an auxiliary spring is positioned between the transverse plate and the axially displaceable means including the rotatable swash plate to press the latter in the axial direction opposite that in which it is pressed by the main spring means.

4. A variable delivery pump according to claim 1 in which the control means is adapted on increasing pressure within the second compartment initially to displace the means including the rotatable swash plate at a uniform rate up to a predetermined pressure and to displace the means including the rotatable swash plate substantially instantly to its maximum possible displacement when the pressure within the second compartment attains the predetermined pressure.

5. A variable delivery pump according to claim 1 in which at least one auxiliary control means disposed in the housing adjacent a secondary bore is connected to the second compartment and is adapted to displace the means including the rotatable swash plate at a rim portion thereof in the same direction as the control means.

6. A variable delivery pump according to claim 1 in which the axially displaceable means including the rotatable swash plate comprises a guide member against which the main spring means presses, the guide member being in sliding contact with the main bore, a first thrust roller bearing between the adjacent end faces of the swash plate and the guide member, a bushing about the end of the drive shaft near the transverse plate and in sliding contact with the main bore, a second thrust bearing between the adjacent end faces of the bushing and the swash plate, a bearing within the bushing journalling the end of the shaft near the transverse plate and displaceable axially on the shaft, an annular flange integral with the end of the bushing adjacent the swash plate, and a port through the annular flange for each secondary bore and registering with the respective secondary bore, the respective plunger extending through the port and the plunger spring means being positioned about the plunger and bearing against the annular flange and the swash plate end of the plunger to force the plunger into contact with the swash plate.

7. A variable delivery pump according to claim 1 in which the main bore portion of the first compartment has a first and a second shoulder spaced from each other, and in which the axially displaceable means including the swash plate comprises a guide member in sliding contact with the

main bore and of a diameter that its axial displacement is limited in one direction by the first shoulder, the swash plate having its end face adjacent the guide member in a plane substantially perpendicular the drive shaft and its other end face at the predetermined inclination to the drive shaft, the main spring means tending to seat the guide member on the first shoulder, a hub integral with the inclined swash plate face and having its cylindrical wall perpendicular to the inclined face, a first thrust bearing between the adjacent end faces of the guide member and the swash plate, a ring rotatable on the swash plate hub integral with the inclined face, a second thrust bearing between the inclined face of the swash plate and the adjacent end face of the rotatable ring, a bushing about the end of the drive shaft near the transverse plate and in sliding contact with the main bore below the second shoulder, a third thrust bearing between the adjacent end faces of the bushing and the hub integral with the inclined face of the swash plate, a bearing within the bushing journalling the end of the shaft near the transverse plate and axially displaceable with the bushing on the shaft, an annular flange integral with the end of the bushing adjacent the swash plate and positioned above the second shoulder, and an opening extending through the flange for each secondary bore and registering with the respective bore, the respective plunger extending through the opening with the plunger spring means being positioned about the plunger and bearing against the flange and the plunger end nearest to the rotatable ring to force the plunger into contact with the rotatable ring, the main spring and the plunger spring means tending to press the flange against the second shoulder, the second shoulder limiting the displacement of the flange in the one direction.

8. A variable delivery pump according to claim 1 in which the axially displaceable means including the rotatable swash plate comprises a guide member in sliding contact with the main bore and against which the main spring means presses, the swash plate, a thrust bearing between the adjacent end faces of the guide member and the swash plate, a bushing about the end of the drive shaft near the transverse plate, the bushing being spaced axially from the swash plate and in sliding contact with the main bore, the end of the shaft near the transverse plate being slidably journaled in the bushing, an annular flange integral with the end face of the bushing adjacent the swash plate, a hollow cylinder of an internal diameter greater than the external diameter of the swash plate integral with the outer rim of the annular flange and of a height to engage the end face of the guide member adjacent the swash plate, an opening in the annular flange for each secondary bore registering with the respective secondary bore, and the plunger spring means is positioned to bear with its ends against the integral flange and the plunger end nearest the swash plate, and in which a plurality of auxiliary control means actuable by the hydraulic pressure in the second compartment is positioned circularly in the housing adjacent the secondary bores and each auxiliary control means includes a plunger adapted to press the rim portion of the annular flange to displace the hollow cylinder and the guide member in the same direction as the control means.

9. A variable delivery pump according to claim 1 in which the control means comprises a valve having a stem and an enlarged head at one end of

the stem, an opening substantially central of and extending through the transverse plate, the stem of the valve extending through the transverse plate opening and bearing with its non-head end against the axially displaceable means, and a hollow cylinder integral with the face of the transverse plate in the second compartment, the hollow cylinder being of such length that the valve head in the position of minimum displacement of the axially displaceable means is still partially within the hollow cylinder, the valve head being in sliding contact with the internal surface of the hollow cylinder.

10. A variable delivery pump according to claim 1 in which the control means comprises a valve having a stem and an enlarged head at one end of the stem, an opening substantially central of and extending through the transverse plate, the stem having a lesser diameter for a length region thereof extending from the head than has the stem in the region at the non-head end thereof, a first hollow cylinder integral with the face of the transverse plate in the first compartment and having an internal diameter such that the non-head region of the stem is slidably guided on the internal surface of the first hollow cylinder, the non-head end of the stem extending beyond the end of the first hollow cylinder and bearing against the axially displaceable means, a second hollow cylinder having an internal diameter of such dimension that the enlarged head is slidably guided on the internal surface of the second hollow cylinder, the second hollow cylinder being integral with the face of the transverse plate in the second compartment and of such a length that the enlarged valve head in the position of minimum displacement of the axially displaceable means is still partially within the second hollow cylinder, a first radial bore in the first hollow cylinder connecting the interior of the first hollow cylinder to the first compartment, the first radial bore being closed by the stem portion having the larger diameter for all axial displacements of the axially displaceable means less than a predetermined displacement, and a second radial bore in the second hollow cylinder connecting the interior of the second hollow cylinder between the plate and the valve head to the second compartment and spaced axially from the first radial bore at such distance that at the predetermined displacement of the axially displaceable means the second radial bore is closed by the enlarged valve head while simultaneously the first radial bore is opened by the valve stem portion of the lesser diameter whereby the valve head under the hydraulic pressure prevailing in the second compartment quickly moves and its integral stem thus simultaneously moves the axially displaceable means from the predetermined displacement position to the maximum displacement position.

11. A variable delivery pump comprising a housing, a main bore substantially central and axial of the housing, a transverse fixed member dividing the main bore into a first and a second compartment, a rotatable drive shaft positioned substantially centrally in the main bore in the first compartment, means axially displaceable along the shaft on the shaft and including a swash plate of constant inclination to the shaft and rotatable therewith, a plurality of secondary bores in the housing below the swash plate and equally distant from the drive shaft and each other, a plunger reciprocable in each secondary

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bore, a liquid inlet bore in each secondary bore extending to a point external of the housing and adapted to be opened and closed by the reciprocation of the respective plunger on rotation of the swash plate, spring means pressing each plunger against the swash plate, a main spring means pressing the axially displaceable means toward the transverse fixed member, secondary spring means resiliently supporting the axially displaceable means on the transverse fixed member, a liquid delivery valve bore connecting each secondary bore to the second compartment, and means for displacing the axially displaceable means in accordance with the pressure of the liquid delivered to the second compartment including a plunger extending from the second compartment into the first compartment and bearing therein against the axially displaceable means, said plunger being aligned axially with the shaft and exerting its force in the same direction against the main spring means as the spring means pressing the secondary bore plungers and the secondary spring means, the axes of the drive shaft, of the secondary bore plungers and of the said plunger being substantially parallel.

12. A variable delivery pump according to claim 11 in which a plurality of auxiliary means for displacing the axially displaceable means is provided within the region of the housing radially beyond the secondary bores, each of the auxiliary means comprising a liquid bore connected to the second compartment, a plunger within the liquid bore and displaceable therein in accordance with the liquid pressure within the second compartment in the same direction as the plunger of the displacing means aligned axially with the shaft and bearing with one end against axially displaceable means, and a venting bore from the liquid bore to a point external of the pump housing, the individual auxiliary means of the plurality being so spaced from each other that the resultant of the forces exerted thereby is substantially axially of the drive shaft.

13. A variable delivery pump according to claim 11 in which a plurality of auxiliary means for displacing the axially displaceable means is provided within the region of the housing radially beyond the secondary bores, each of the auxiliary means comprising a liquid bore, a channel connecting the bottom region of the liquid bore to the second compartment, and a plunger within the liquid bore of which one end is adapted to engage the axially displaceable means, the said liquid bore plunger being at all times under the pressure of the liquid in the second compartment, the individual auxiliary means of the plurality being so spaced from each other and relative the driving shaft that the resultant of the forces exerted by the said liquid bore plungers on the axially displaceable means is substantially axially of the shaft.

14. A variable delivery pump according to claim 11 in which the means for displacing the axially displaceable means in accordance with the hydraulic pressure prevailing in the second compartment of the liquid delivered thereto is adapted on increasing pressure therein to displace the axially displaceable means including the swash plate at a uniform rate up to a predetermined pressure and to displace such means substantially instantly to the maximum possible displacement position when the hydraulic pressure within the second compartment attains the predetermined pressure, and in which a plurality

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of auxiliary means for displacing the axially displaceable means including the rotatable swash plate is provided within the housing radially beyond the secondary bores, each of the auxiliary means comprising a plunger bore of which an intermediate region of predetermined length has a larger internal diameter than the two end portions of the bore, a plunger within the plunger bore, a spring within the plunger bore acting against the plunger to press one end thereof against the axially displaceable means, a channel from the second compartment to convey liquid therefrom to the region of the plunger bore substantially immediately adjacent the intermediate region thereof of larger internal diameter, the plunger closing the channel for all displacements of the axially displaceable means from minimum to that corresponding to the predetermined pressure, a venting bore from the enlarged intermediate region of the plunger bore to a point external of the pump housing, the plunger closing the venting bore substantially simultaneously with opening the channel, whereby at the predetermined pressure liquid from the second compartment flows into the plunger bore and propels the plunger substantially instantly to the maximum displacement position of the axially displaceable means, and a plurality of openings through the plunger positioned lengthwise the plunger so that at all displacements of the axially displaceable means corresponding to pressures less than the predetermined pressure the plunger bore is connected to the venting bore but is disconnected from the venting bore at all displacements of the axially displaceable means from that corresponding to the predetermined pressure to and including the maximum displacement.

15. A variable delivery pump according to claim 11 in which a plurality of auxiliary means for displacing the axially displaceable means is provided within the region of the housing laterally beyond the secondary bores, each of the auxiliary means comprising a plunger bore, a displaceable plunger within the plunger bore, a spring between one end of the plunger bore and one end of the plunger pressing the other end of the plunger against the axially displaceable means, and a liquid channel connecting the one end of the plunger bore to the region of an adjacent secondary bore below the liquid inlet bore thereof, the individual auxiliary means of the plurality being so spaced from each other and the drive shaft that the resultant of the forces exerted by the respective plungers thereof on the axially displaceable means is substantially axially of the drive shaft.

16. A variable delivery pump according to claim 11 in which the plurality of secondary bores comprises a first plurality of secondary bores of a first diameter and a second plurality of secondary bores of a second diameter smaller than the first diameter, the reciprocable plungers in the respective secondary bores being of corresponding external diameters, and in which a plurality of auxiliary means for displacing the axially displaceable means is provided within the region of the housing laterally beyond the secondary bores, each of the auxiliary means comprising a plunger bore, a displaceable plunger within the bore, a spring between one end of the plunger bore and one end of the plunger pressing the other end of the displaceable plunger against the axially displaceable means, and a liquid channel connecting the one end of the plunger bore to the region of an adjacent secondary bore

of the second plurality of secondary bores below the liquid inlet bore thereof, the individual auxiliary means of the plurality being so spaced from each other and the drive shaft that the resultant of the forces exerted by the respective plungers thereof on the axially displaceable means lies substantially axially of the drive shaft.

17. A variable delivery pump according to claim 11 in which the plurality of secondary bores comprises a first plurality of secondary bores of a given diameter and a second plurality of secondary bores of a diameter less than the given diameter, the reciprocable plungers in the respective secondary bores of each plurality being of corresponding cross-sections, and in which a plurality corresponding in number to the number of secondary bores in the second plurality of auxiliary means for displacing the axially displaceable means is provided within the region of the housing laterally beyond the secondary bores, each of the auxiliary means being positioned adjacent a secondary bore of the second plurality of secondary bores and comprising a plunger bore, a displaceable plunger within and guided by the plunger bore and of a cross-section such that the sum of its cross-section and the cross-section of the reciprocable plunger of the secondary bore of the second plurality of bores is equal to the cross-section of a reciprocable plunger in a secondary bore of the first plurality of secondary bores, a spring between one end of the plunger bore and one end of the displaceable plunger to press its other end against the axially displaceable means, and a liquid channel connecting the one end of the plunger bore to the region of the adjacent secondary bore of the second plurality of secondary bores below the liquid inlet thereof.

18. A variable delivery pump according to claim 11 in which the means for displacing the axially displaceable means in accordance with the hydraulic pressure of the delivered liquid in the second compartment is adapted on increasing pressure therewithin to displace the axially displaceable means including the rotatable swash plate at a uniform rate up to a predetermined pressure and at the predetermined pressure substantially instantly to the maximum possible displacement, and in which a first and a second plurality of auxiliary means for displacing the axially displaceable means are provided within the region of the housing laterally beyond the secondary bores, each of the first plurality of auxiliary means comprising a plunger bore, a liquid channel connecting the bottom region of the plunger bore to the second compartment, and a plunger within the plunger bore of which one end is adapted to engage the axially displaceable means under the pressure of liquid in the bore from the channel, and each of the secondary plurality of auxiliary means comprising a plunger bore of which an intermediate region of predetermined length has a larger internal diameter than the two end portions of the bore, a plunger within plunger bore, a spring within the plunger bore acting against the plunger to press an end thereof against the axially displaceable means, a channel from the second compartment to convey liquid therefrom to the region of the plunger bore adjacent the intermediate region thereof remote from the axially displaceable means, a venting bore from the intermediate region of the plunger bore to externally the pump housing, the plunger maintaining the channel closed and the venting bore

open for all displacements of the axially displaceable means from minimum displacement to that corresponding to the predetermined pressure and on opening the channel simultaneously closing the venting bore whereby at the predetermined pressure the liquid under pressure flowing into the plunger bore propels the plunger substantially instantly to the maximum displacement position of the axially displaceable means, and at least one port through the plunger in such location thereon to its spring-pressed end that at all displacements corresponding to pressures less than the predetermined pressure the plunger bore is connected to the venting bore and at all displacements exceeding the displacement corresponding to the predetermined pressure is disconnected from the venting bore, the individual auxiliary means of the first and second plurality being alternatively positioned within the pump housing with one auxiliary means of the one plurality between two auxiliary means of the other plurality.

19. A variable delivery pump comprising a housing, a main bore substantially central and axially of the housing, a transverse fixed member dividing the main bore into a first and a second compartment, a rotatable drive shaft substantially central of the main bore in the first compartment, means axially displaceable along the shaft between a predetermined minimum and maximum limit and including a swash plate having at least one face at constant inclination to the shaft and rotatable therewith, a first plurality and a second plurality of secondary bores within the housing below the position occupied by the inclined face of the swash plate in the minimum displacement position of the axially displaceable means, each of the secondary bores of the first plurality being of a predetermined diameter and each of the secondary bores of the second plurality being of a diameter smaller than the predetermined diameter, a plunger reciprocably slidable in each secondary bore, a liquid inlet bore in each secondary bore extending to a point external of the housing and adapted to be opened and closed by the reciprocation of the respective plunger on rotation of the swash plate, the inlet bore of each secondary bore of the first plurality being so positioned relative to the delivery end thereof that it is opened and closed on each reciprocation irrespective of the displaced position of the axially displaceable means while the inlet bore of each secondary bore of the second plurality is so positioned relative to the liquid delivery end thereof that it remains closed for each plunger reciprocation when the axially displaceable means occupies a position between the minimum limit and a predetermined position but is opened and closed for each plunger reciprocation when the axially displaceable means is positioned between the predetermined position and the maximum limit, an auxiliary inlet port in each secondary bore of the second plurality positioned adjacent the liquid delivery end thereof, a valve within the auxiliary inlet port biased so that it opens only on the suction stroke of the plunger within the respective secondary bore while the inlet bore thereof remains closed, spring means pressing one end of each plunger against the swash plate, main spring means tending at all times to press the axially displaceable means to the predetermined minimum limit, secondary spring means resiliently supporting the axially displaceable means on the transverse fixed member, liquid

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channels connecting the delivery end of each secondary bore to the second compartment, a biased valve in each channel closing the channel on each suction stroke of the plunger and tending to open the channel on each delivery stroke thereof, and means for displacing the axially displaceable means including the rotatable swash plate against the main spring means in accordance with the pressure of the delivered liquid in the second compartment including at least one plunger extending from the second compartment

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into the first compartment and bearing within the first compartment against the axially displaceable means.

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