

May 18, 1954

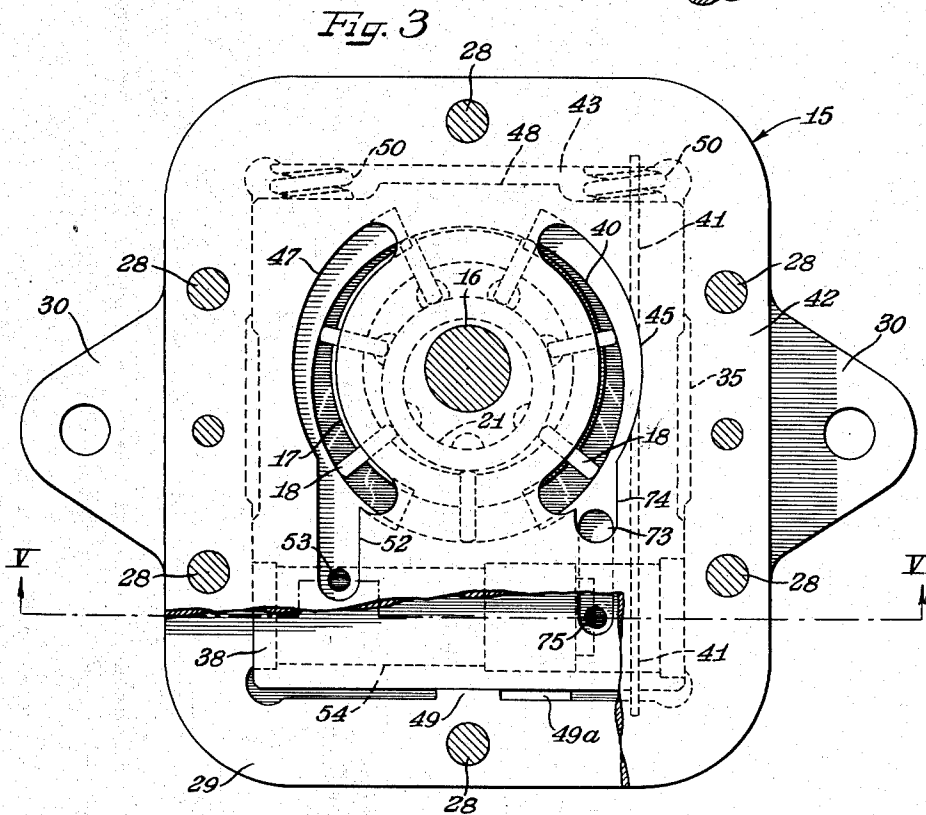
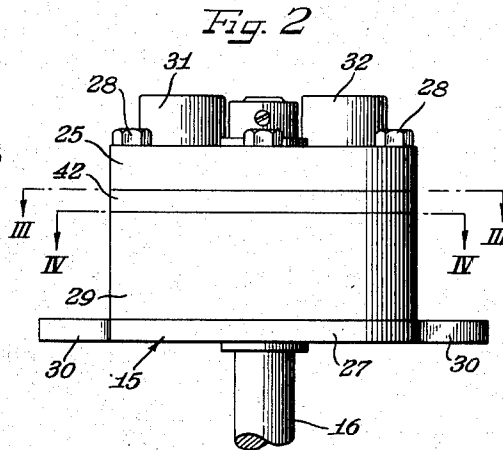
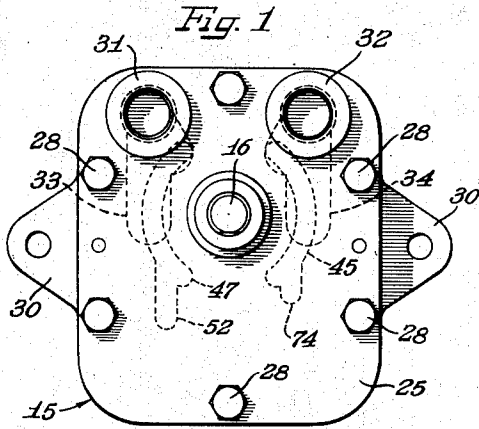
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2,678,607

CONSTANT PRESSURE VARIABLE DISPLACEMENT PUMP

Filed April 2, 1948

6 Sheets-Sheet 1



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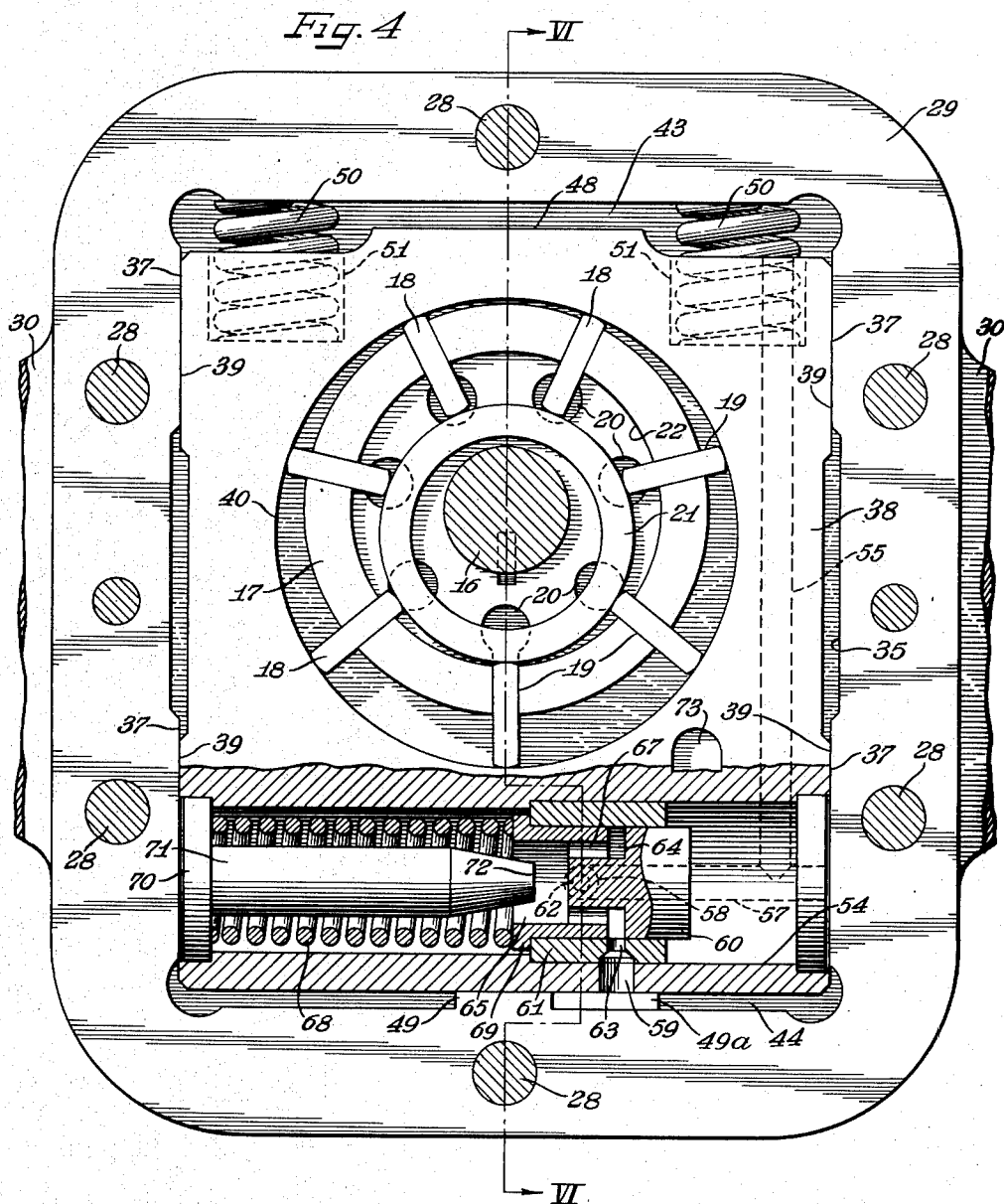
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CONSTANT PRESSURE VARIABLE DISPLACEMENT PUMP

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6 Sheets-Sheet 2



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6 Sheets-Sheet 3

Fig. 5

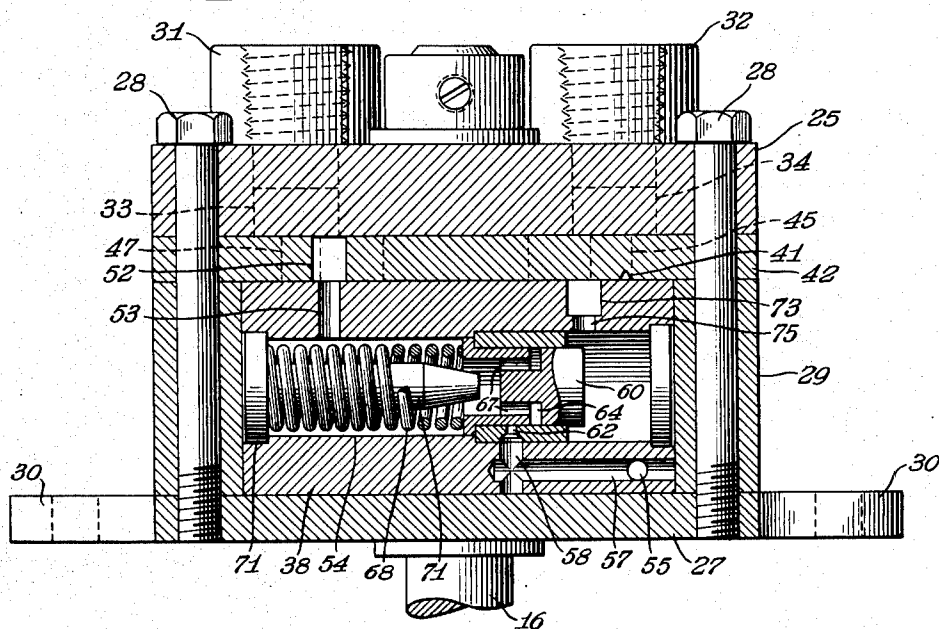
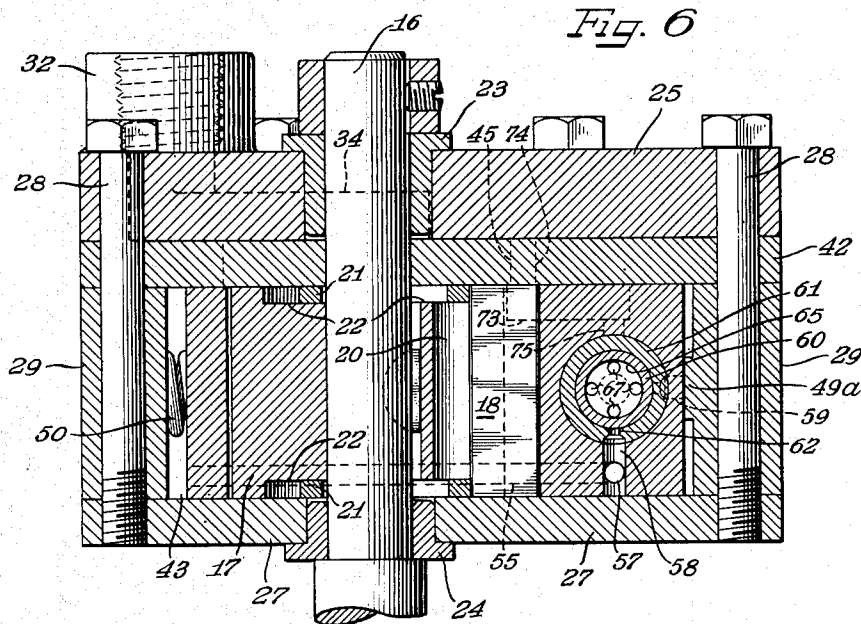


Fig. 6



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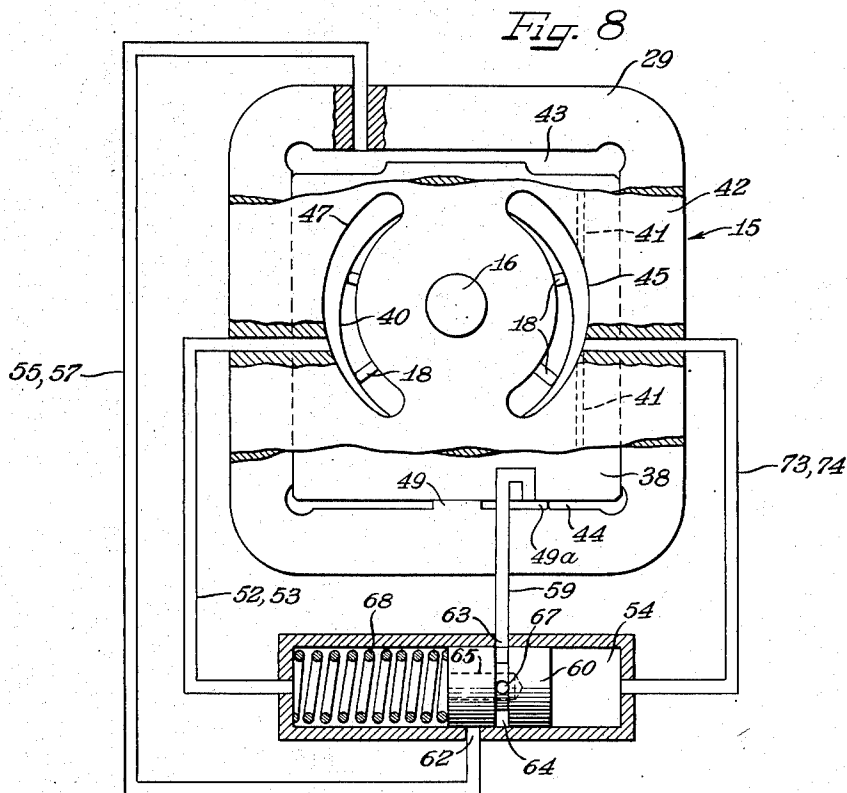
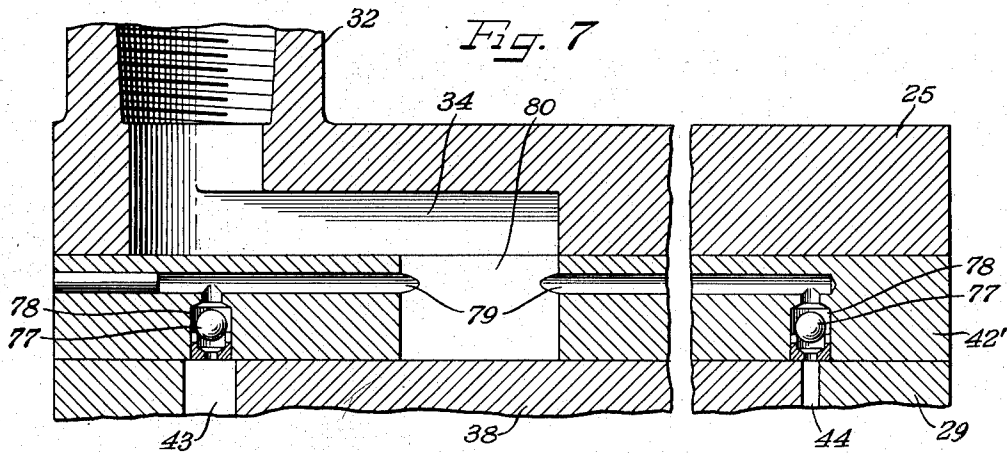
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CONSTANT PRESSURE VARIABLE DISPLACEMENT PUMP

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6 Sheets-Sheet 4



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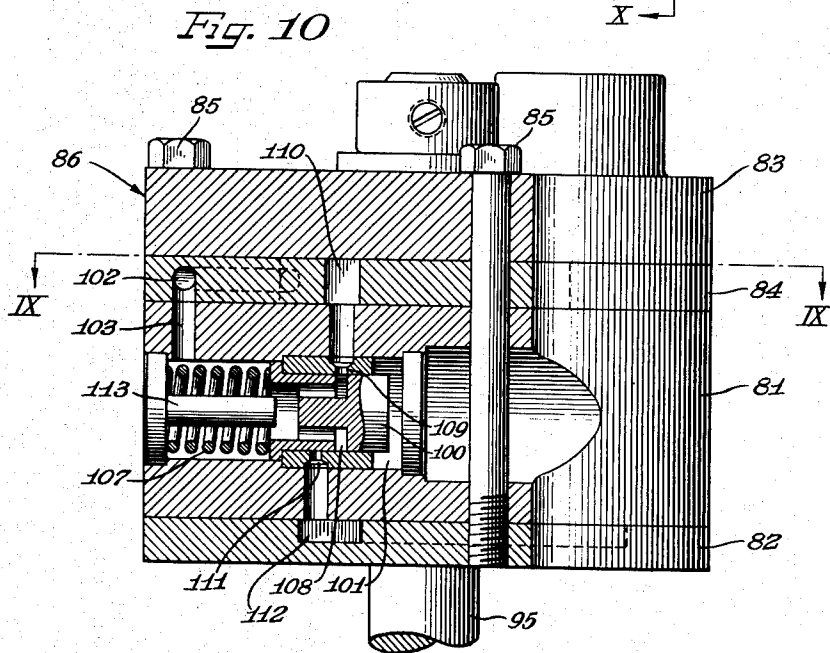
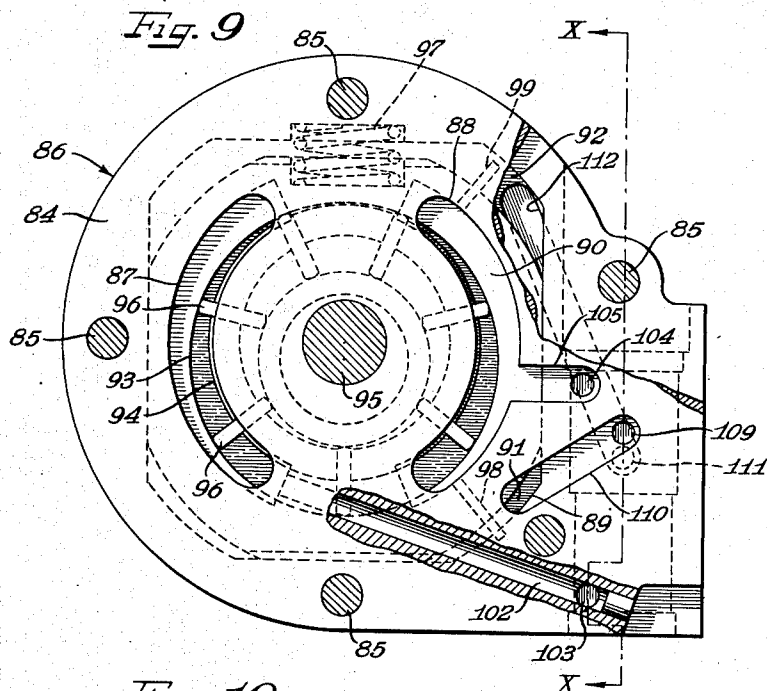
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CONSTANT PRESSURE VARIABLE DISPLACEMENT PUMP

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6 Sheets-Sheet 6

Fig. 11

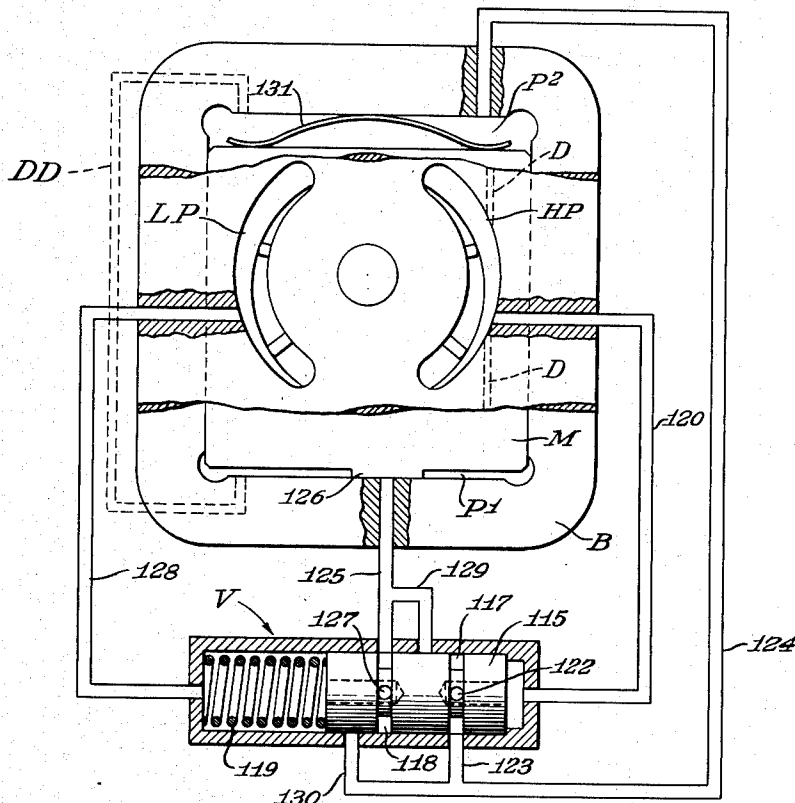


Fig. 12

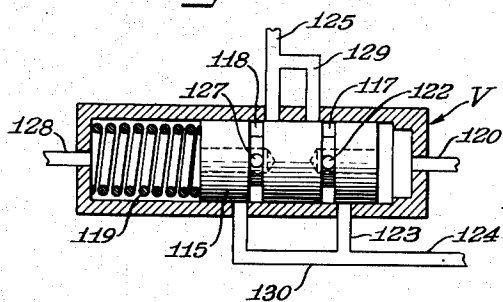
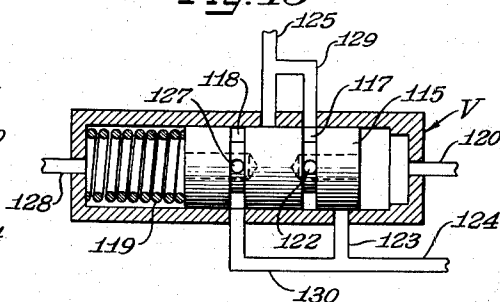


Fig. 13



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UNITED STATES PATENT OFFICE

2,678,607

CONSTANT PRESSURE VARIABLE
DISPLACEMENT PUMP

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Application April 2, 1948, Serial No. 18,558

13 Claims. (Cl. 103—120)

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The present invention relates to improvements in constant pressure variable displacement pumps and more particularly to pumps of this character which are automatically adjustable in response to operating conditions and require-
ments encountered during performance of the pump.

Numerous attempts have heretofore been made to supply rotary, vane type variable displacement pumps having mechanical or more or less automatic control. However, the prior devices have inherently lacked or have been deficient in various characteristics which would render them satisfactory under as great a range of operating requirements and conditions as desirable. For example, certain constructions lack stability in that they will vibrate or chatter under certain operating conditions. They may be sluggish in operation so that undue back pressure develops before a change in displacement occurs. Changes in displacement may be accompanied by too great a pressure drop. Some are badly affected by variations in temperature. Foaming of the hydraulic fluid frequently detrimentally affects operation of the pumps. Some constructions have lacked adequate ruggedness for operation under high pressures. Speed ranges for certain forms of the pumps have been seriously restricted.

An important object of the present invention is to provide a constant pressure variable displacement pump construction which satisfactorily overcomes the limitations and deficiencies of prior pumps of this character as enumerated hereinbefore, and to improve this kind of pump in various respects.

Another object of the invention is to improve constant pressure variable displacement pumps to attain great stability and freedom from vibration or chatter.

A further object of the invention is to provide improvements in pumps of the character referred to wherein the available fluid at high speeds remains substantially constant so that the pressure and volume remain at a desired value.

Still another object of the invention is to provide constant pressure variable displacement pumps of improved construction wherein a wide range of temperature conditions are adapted to be accommodated satisfactorily.

Yet another object of the invention is to provide improved constant pressure variable displacement pump construction which will operate efficiently in spite of foaming of the hydraulic fluid.

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A still further object of the invention is to provide constant pressure variable displacement pump structure of relatively simple, compact, rugged and essentially trouble-free character.

Yet a further object of the invention is to provide improved displacement varying control means for rotary vane type pumps.

Other objects, features and advantages of the present invention will be readily apparent from the following detailed description of certain preferred embodiments thereof taken in conjunction with the accompanying six sheets of drawings in which:

Figure 1 is an elevational view of one face of a pump unit embodying features of the invention;

Figure 2 is an end elevational view of the pump unit;

Figure 3 is a sectional elevational view through the pump unit, taken substantially on line III—III of Figure 2 and on an enlarged scale.

Figure 4 is a sectional elevational view through the pump unit taken substantially on the line IV—IV of Figure 2, and on a substantially enlarged scale, with certain portions broken away for clarity of illustration.

Figure 5 is a sectional view through the pump unit taken substantially on the line V—V of Figure 3;

Figure 6 is a sectional elevational view taken substantially on the line VI—VI of Figure 4 and on a reduced scale;

Figure 7 is a fragmentary sectional elevational view of a slight modification in one portion of the pump unit;

Figure 8 is a diagrammatic view showing the hydraulic control circuit for the pump unit of Figure 1;

Figure 9 is a sectional elevational view through a modified form of pump unit, with certain parts broken away for purpose of illustration and taken substantially on the line IX—IX of Figure 10;

Figure 10 is a sectional view taken substantially on the line X—X of Figure 9;

Figure 11 is a diagrammatic view showing a modified displacement control arrangement which is applicable to either of the forms of Figure 1 or 9;

Figure 12 is a fragmentary diagrammatic, sectional elevational view showing the control valve of the form of Figure 11 in a different operative position than in Figure 11; and

Figure 13 shows the control valve in still another operative position.

A pump unit 15 embodying the principles of the present invention, and as shown in Figures 1 to

6, inclusive, is of the type wherein a shaft 16 drives a rotor 17, keyed or otherwise secured fixedly thereto and with which is associated a series of radially reciprocable fluid impelling vanes 18.

The rotor 17 is of a known type having radial slots 19 for the vanes 18, the inner ends of the slots being formed with circular enlargements 20 for freedom of action, and the inner edges of the vanes being in engagement with identical control rings 21 located in appropriate end recesses 22 in the rotor (Figures 4 and 6).

The shaft 16 is journaled in appropriate bearings 23 and 24 carried by respective opposite face plates 25 and 27, respectively, secured as by means of screws 28 to opposite sides of a hollow body block 29. For attaching the unit in place in association with apparatus with which the unit may be employed, the face plate 27 may be provided with apertured attachment ears 38. The face plate 25 may be formed with an inlet boss 31 and an outlet boss 32. These bosses are centrally bored and appropriately tapped to receive hydraulic fluid ducts and communicate with appropriate communication undercuts 33 and 34, respectively, in the inner face of the plate 25 (Figures 1 and 5).

According to the present invention means are provided within the pump unit 15 for maintaining nearly as practicable a constant pressure of the hydraulic fluid at the outlet 32, in spite of wide variation in speed of the shaft 16 and thereby of the rotor 17, as well as a wide range of fluid demand at the outlet 32 or fluctuations in the fluid supply at the inlet 31. This is accomplished automatically responsive to internal fluid pressures. To this end, the body block 29 is formed internally with a preferably rectangular chamber 35 of substantially greater area than required for the pumping sweep of the pump vanes 18, and formed at opposite sides with bearing pads 37. Within the chamber 35 is reciprocably slidably disposed a generally rectangular modulator block 38 which is shorter by predetermined extent than the length of the chamber 35 and has bearing pads 39 at its opposite sides which are slidably in engaged relation with the bearing pads 37 of the body block within the chamber. A circular pump chamber 40 in the modulator block accommodates the pump rotor 17 and is of a diameter to have the outer edges of the rotor vanes 18 bear uniformly slidably against the pump chamber wall. The relation of the modulator block 38 is such to the shaft 16 and the chamber 35 in the body block 29 that when the modulator block is slidably shifted fully to one end of the chamber 35, in the present instance to the upper end as viewed in Figure 4, full concentricity of the pump chamber 40 with the rotor 17 is attained. When the modulator block 38 is shifted to the opposite extreme end of the chamber 37, maximum eccentricity of the pumping chamber 40 relative to the rotor 17 is attained. Thus, rectilinear shifting of the modulator block 38 is effective to vary and control the displacement of the pump from zero to maximum.

Means are provided for utilizing the dynamic fluid pressure of the pump for not only holding the modulator 38 in functional adjustment but also for slidably adjusting the modulator in both of its opposite directions of pump displacement modifying movement. For this purpose, the high pressure side of the pump is placed in communication with both opposite ends of the body block

chamber 35 so that the high pressure can act upon the respective opposite ends of the modulator 38. A convenient device for this comprises a passageway duct 41 (Figures 3 and 5) which may be in any preferred form for manufacturing and assembly convenience and is here formed as a groove in the inner face of a distributor plate 42 coextensive with and clamped between the face plate 25 and the body block 29. The groove 41 is of a length to extend to the opposite extremities of the chamber 35 so as to be in constant communication with pressure areas or sub-chambers 43 and 44 at the respective opposite ends of the modulator 38.

High pressure fluid communication between the pump chamber 40 and the outlet passage 32 through the distributor plate 42 is effected by way of a preferably semi-circular or generally kidney-shaped discharge port 45 of such length and disposition as to afford resistance-free pressure communication with the high pressure side of the pump chamber 40. As best seen in Figure 3, the high pressure communication duct groove 41 cuts across the high pressure port 45 so that equal pressure conductivity is attained for each opposite end portion of the duct 41.

Fluid inlet communication through the distributor plate 42 is attained through an inlet port 47 extending therethrough. This port is substantially the counterpart of the discharge port 45 but is in communication at the inside with the low pressure or inlet side of the pump chamber 40 and at the outside with the undercut inlet passage 33 leading from the inlet 31 in the side plate 25 of the pump unit.

The high pressure delivered by the pump through the duct or communication passageway 41 to the opposite ends of the modulator 38 tends normally to maintain the modulator in what may be called dynamic pressure balance, holding the modulator firmly against any tendency to vibrate or chatter. This is implemented by having the pressure areas 43 and 44 at the opposite ends of the modulator block adequately isolated from the low pressure side of the pump by the large bearing areas between the flat faces of the modulator block 38 and the opposing flat close slidable bearing surfaces of the face plate 27 and the distributor plate 42 between which the modulator block is closely confined in free slidable relation. The pressure areas 43 and 44, of course, are also isolated from one another by the large intervening bearing areas between the modulator block and the opposing plates of the housing casing and by the close bearing relation of the bearing pads 37 and 39 at the sides of the modulator block.

In order to insure that the pressure areas 43 and 44 will be at all times open to the high pressure fluid from the pump, respective spacers are provided between the opposing walls of the modulator block 38 and the end walls of the chamber 35. These comprise in the present instance a spacer pad 48 projecting from the modulator block toward the opposing chamber wall within the pressure area 43 and a spacer pad 49 projecting from the chamber wall within the pressure area 44 for engagement by the opposing end of the modulator block. Herein the arrangement is such that engagement of the modulator block 38 with the spacer pad 48, as shown in Figures 3 and 4, occurs at the maximum eccentricity of the pump chamber 40 relative to the rotor 17, while engagement of the spacer pad 48 on the modulator block with the opposing chamber wall

occurs at the point of concentricity of the pump chamber with the rotor.

At the start of operation of the pump 15, it is, of course, highly desirable that there be maximum displacement of hydraulic fluid by the rotor vanes 18 so as to develop the desired pressure as quickly as practicable. In order to assure this, priming means are provided for normally biasing the modulator block 38 to the position wherein the pump chamber 40 attains maximum eccentricity relative to the rotor 17. Herein such means comprises biasing spring structure in the form of a pair of similar coiled compression springs 50 seated in appropriate spring sockets 51 adjacent the opposite sides of the modulator block in the end face thereof which includes the spacer pad 48 and with the outer ends of the springs bearing against the opposing wall of the chamber 35 within the pressure area 43. The springs 50 acting upon the modulator block 38 assure that when the pump stops the modulator block will not remain in idling relation to the rotor 17, that is, with the pump chamber 40 concentric with the rotor 17. Since the modulator block 38 is thus positively biased or primed toward eccentricity relative to the rotor 17, starting of the rotor for pumping always finds the pump chamber 40 disposed for fluid displacement.

During operation of the pump, however, fluid pressure is the medium for controlling the position of the modulator block 38. To this end control means are provided which operate to render the pressure areas 43 and 44 automatically responsive to variations in pressure in the pumping system to relatively alter the pressure fluid volume in the pressure areas for shifting the modulator block 38 reciprocally, thereby maintaining a mean pressure output at the pump outlet. Herein such means comprise an arrangement for controlled, automatically selective communication between the low pressure side of the pump and the respective pressure areas 43 and 44 to bleed sufficient pressure fluid therefrom to effect dynamic unbalance to the extent demanded to adjust the pump displacement for maintenance of the predetermined mean output pressure. Accordingly, a lead-off branch 52 of the intake port 47 (Figures 3 and 5) communicates by way of a bore or orifice 53 through the contiguous face of the modulator block 38 with a transverse control valve chamber bore 54 within the modulator block. Communication between the pressure area 43 and the control chamber 54 is adapted to be effected through a passage 55 extending longitudinally through the high pressure side portion of the modulator 38 and having a leg 57 extending transversely of the modulator parallel to and spaced from the control chamber 54 and which in turn has a port 58 opening into the control chamber (Figures 4, 5 and 6). Communication between the control chamber and the pressure area 44 is effected through a port 59 that opens through the end of the modulator 38. In the fully eccentric condition of the modulator 38, the port 59 is blocked by a lateral extension 49a of the spacer pad 49. It may be observed that the ports 58 and 59 are relatively offset considered longitudinally of the control chamber 54 and enter the chamber approximately 90° apart.

For controlling communication of the low pressure port or orifice 53 with either of the ports 58 or 59 leading to the respective pressure areas, a valve 60 is provided. This preferably comprises a cylindrical plug-type of valve body slidably bearing in a bushing 61 secured concen-

trically in the control chamber 54 in the area thereof through which the ports 58 and 59 communicate with the control chamber. A reduced diameter port 62 through the bushing 61 registers with the bore port 58 and a reduced diameter port 63 through the bushing registers with the port 59.

The offset spacing between the ports 62 and 63 is preferably slightly greater than the width of an annular groove 64 formed in an intermediate portion of the periphery of the valve member 60 and adapted in one longitudinal position of the valve member to register with the port 63 and in another longitudinal position to register with the port 62. Communication between the groove 64 and a counterbore 65 in the end portion of the valve member 60 exposed to low pressure within the control chamber 54 and extending short of the groove 64 is provided by a plurality of longitudinally extending communication bores 67.

The valve member 60 is normally biased to assume a longitudinal position wherein the groove 64 registers with the port 63 leading by way of the port 69 to the pressure area 44. This is effected by means such as a coil compression spring 68 bearing against the low pressure end of the valve member 60 to drive the same normally to the right, as seen in Figure 4, until a radially projecting stop flange 69 on the engaged end of the valve member bears against the adjacent end of the bushing 61 which for this purpose has a wall thickness to project into the path of the stop flange 69 clear of the adjacent wall of the control chamber 54. The outer end of the spring 68 bears against a plug 70 which closes the low pressure end of the control chamber 54 fluid tight and which has a stop pin or stem 71 projecting therefrom axially through the control chamber 54 to a blunt tapered tip 72 serving as a limit stop upon movement of the valve plug 60 to a predetermined limited distance in opposition to the biasing spring 68 to the position wherein the annular communication groove 64 in the valve plug registers with the port 62 in the valve bushing.

It will thus be apparent that in the absence of counterforce, the spring 68 will maintain the valve member 60 in the position wherein a passage is afforded between the low pressure side of the control chamber 54 and the port 59 by way of the counterbore 65, the communication bores 67, the communication groove 64, and the port 63, while at the same time the valve member 60 fully blocks the port 62. Thus, at the start of operation, the pressure area 43 is entirely cut off by the valve 60 from the low pressure side of the pump; and the pressure area 44 is blocked from communication with the low pressure side of the pump by the blocking pad 49a covering the port 59 as a result of the modulator biasing effect of the springs 50. Hence, the full initial pumping effect of the rotor 17 is directed for quick response to the outlet 32 without any unnecessary fluid bleed-off. If before the predetermined operating pressure is reached any force tends to shift the modulator from its initial position of maximum eccentricity relative to the rotor 17, the bleed-off port 59 is uncovered and the resulting pressure reduction in the chamber 44 effects a dynamic unbalance that assures virtually full eccentricity of the modulator 38 until substantially the rated pressure of the pump is attained.

The valve biasing spring 68 is selected to afford, following a predetermined degree of initial com-

pression, resistance to compression equal to the predetermined pressure rating of the pump. That is, the spring 68 is designed to hold the valve member 60 in its spring biased limit position with a pressure load which is slightly less than the predetermined operating pressure for which the pump is rated; but after relatively slight predetermined movement of the valve body 60 in opposition to the spring, loading thereof stiffens it to attain the desired force or pressure balance. Such movement carries the communication groove 64 in the valve body intermediate and out of communication with the ports 62 and 63 so that solid areas of the valve member 60 will block both of the ports 62 and 63 and substantially equal dynamic modulator holding pressure will prevail in the pressure areas 43 and 44.

Thrust in opposition to the spring 68 is automatically effected by subjecting the head of the valve member 60 to dynamic pressure from the high pressure side of the pump. Hence, as the pressure fluctuates, the valve member 60 will respond and by selective exposure or communication of the pressure areas 43 and 44 to or with the low pressure side of the pump effect adjustment of the modulator block 38 to control pump displacement and maintain the desired mean pumping pressure.

Continuous exposure of the lead end of the valve member 60 to the high pressure side of the pump is effected by way of a groove 73 formed in that face of the modulator block 38 which opposes the distributor plate 42 and communicating at one end with a branch 74 from the high pressure outlet port 45. This communication is constant throughout the full range of reciprocal adjustment of the modulator 38. At its opposite end the communication groove 73 has a port 75 opening into the control chamber 54 in front of the valve member 60.

For a quick review of the operation of the pump and the displacement control means, reference may be had to the schematic illustration in Figure 8. The relationship of parts shown is as found in the non-operating condition of the motor unit. In this condition, the pressure areas 43 and 44 are in equal communication with the high pressure side of the pump but are isolated from the low pressure side of the pump until the rotor 17 accelerates and the modulator 38 shifts enough to open the bleed-off port 59 whereby the pressure area 44 is relieved by way of the passage afforded by the port 59, the peripheral groove 64 and the passageway 67 in the valve member 60 to the rear or biased end of the valve member past the biasing spring 68 and by way of the passageway 52, 53 to the low pressure side of the pump at the inlet port 47. As a result, the modulator 38 maintains initially maximum eccentricity of the pump chamber 40 relative to the pump rotor while the predetermined rated pressure of the pump is quickly attained. This pressure becomes active through the passageway 73, 74 and the control chamber 54 upon the valve member 60 to move the latter against the load of the spring 68 to disconnect the groove 64 in the valve member from the passage 59, thus isolating the pressure area 44, as well as the pressure area 43, from the low pressure side of the pump and affording a dynamic pressure balance in the pressure areas through the high pressure duct 41.

Should pump pressure tend to increase beyond the predetermined value for which the system is rated, the excess pressure, reflected through the

passageway 73, 74 upon the head of the valve member 60 causes the same to move further in opposition to the spring 68 and open bleed-off communication between the pressure area 43 and the low pressure side of the pump by way of the passageway 55, 57, the port 62 and the valve groove 64 and port 67 through the rear or suction end of the control chamber 54 and the passageway 52, 53. As a result the modulator block 38 is caused to shift slidably and reduce the pump displacement, thereby reducing the pump pressure. Promptly upon adjustment to the desired pressure, the valve member 60, under the influence of the biasing spring 68, returns to the neutral position wherein the communication groove 64 of the valve member is disposed between and out of communication with the ports 62 and 63. Thus, throughout the operation of the pump any fluctuations that may occur, for example, by speed up of the rotor, variations in fluid supply or demand, and the like, are promptly reflected in automatic adjustment of the valve member 60 to control the pressure areas 43 and 44 and appropriately adjust the modulator block reciprocally.

However, by reason of the space interval between the control ports 62 and 63, tendency of the control means to "hunt" in response to relatively inconsequential fluctuations in pressure is minimized. This eliminates tendency of the pump to chatter or vibrate and assures positive, smooth and uniform control thereof for consequential fluctuations in pressure. While the ports 62 and 63 are blocked, of course, efficient dynamic hydraulic pressure balance prevails in the pressure areas 43 and 44 to hold the modulator block 38 substantially against displacement.

In practice, it is preferred to have the neutral space interval between the ports 62 and 63 slightly greater than the width of the valve groove 64. When the groove 64 effects communication with either of the ports 62 or 63 there is virtually instantaneous response by whatever increment demanded by pressure fluctuations at the high pressure side of the pump for adjustment of the modulator block 38. This assures minimum pressure rise or drop in the pumping system from the desired mean pressure.

Among the many other practical advantages in a pump equipped with a control arrangement as described, it has been found that quite substantial variations in fluid temperatures can be accommodated in the pump satisfactorily and without appreciable deviation from the mean pressure. It has also been found that even highly foamy fluid is handled by the pump with substantially the same efficiency as non-foamy liquid. Of perhaps even more importance is the fact that whereas in prior art devices the available fluid would drop off at high speed, no drop-off occurs in the present pump within an extremely wide range.

It has been found desirable at times to provide restraint upon over-rapid shifting of the modulator block 38 for pump displacement modulation under certain conditions in operation. Accordingly, it has been desirable to provide means, as shown in Figure 7, for controlling the high pressure communication duct between the areas 43 and 44 and the high pressure side of the pump. Accordingly, a somewhat thicker distributor plate 42' is provided between the face plate 25 and the body or casing block 29 to provide adequate accommodations for appropriate check valves such as ball valves 77 in ports 78

between the ends of a pressure duct 79 and the respective pressure areas 43 and 44. The pressure duct 79, of course, replaces the groove duct 41 of Figures 1 to 6 and communicates with a pressure outlet port 80 through the distributor plate 42' and communicating with the undercut passageway 34 for the outlet 32 in the face plate 25. Through this arrangement, sudden pressure drops in either of the pressure areas 43 or 44, with a corresponding pressure surge in the remaining pressure area, and which might tend to cause back pressure in the suddenly relieved pressure area venting through the associated arm of the pressure duct 79, will be restrained by the appropriate check valve 77. Thereby jerkiness or hammering in the modulator block control circuits is avoided and smooth, quiet, efficient adjustment of the modulator block is assured.

In Figures 9 and 10 is shown a modified form of pump 85 which in functional respects is the same as the pump 15 already described, but in which the physical arrangement is somewhat different to have the control valve structure in the pump housing instead of carried by the modulator block. To this end, the pump unit 85 comprises a hollow body block 81 having a face plate 82 on one side and a face plate 83 on the other side with a distributor plate 84 interposed between the face plate 83 and the body block 81, the stacked assembly being secured together as by means such as screws 85. Except for slightly different edge contour, the face plate 83 is the same as the previously described face plate 25 and has appropriate fluid inlet and outlet passages which communicate with semi-circular kidney shape inlet and outlet ports 87 and 88, respectively, in the distributor plate 84. A straight walled chamber 89 within the body block 81 has a modulator block 90 rectilinearly slidably mounted therein and affords pressure areas 91 and 92, respectively, at the opposite ends of the modulator block. A circular pump chamber 93 in the modulator block normally eccentrically encircles a rotor 94 driven by a shaft 95 and having radially slidable vanes 96 just like the rotor 17 of the pump unit 15. A priming spring 97 acts in the non-operating condition of the pump to urge the modulator block 90 toward eccentric relation relative to the rotor 94 so as to assure that in starting the pump the modulator block will not be in a position of neutrality or zero fluid displacement. Communication between the pressure areas 91 and 92 and the high pressure side of the pump is effected through the medium of appropriate respective communication ducts 98 and 99 in the modulator block opposing face of the distributor plate 84 and leading from the outlet port 88 therein.

Reciprocal adjustment of the modulator block 90 is effected in substantially the same manner as in the pump unit 15 except that a control valve 100 operatively mounted in a control chamber 101 in the body block 81 at one side of the modulator block chamber 89 is utilized. Low pressure or suction communication between the pump and one end of the control chamber 101 is effected by way of a passage 102 that is formed in the distributor plate 84 and which communicates by way of a port 103 with the control chamber. High pressure communication between the opposite end of the control chamber 101 and the high pressure side of the pump is effected by way of a port 104 in the body block which communicates with an arm 105 leading from the discharge port 88 in the distributor plate.

The control valve 100 is in all essential respects the same as the control valve 60 of the pump unit 15 and comprises a cylindrical body, a solid end of which is exposed to high pressure in the control chamber 101 and the opposite end of which is engaged by a biasing spring 107 of predetermined load and against the force of which the valve member 100 is driven by high pressure exerted against the high pressure end thereof.

Upon attainment of the predetermined pressure in the high pressure end of the control chamber 101, the valve member 100 is driven a predetermined distance in opposition to the biasing spring 107 until a peripheral groove 108 in the valve member shifts out of registry with a port 109 which communicates by way of a passage 110 in the distributor plate 84 with the pressure area 91 and by which communication is selectively effected with the low pressure side of the pump. At the mean pressure, the valve groove 108 is disposed intermediate the port 109 and a low pressure communication port 111, which communicates by way of a passage 112 in the face plate 82 with the pressure area 92. Limit upon shifting of the valve member 100 in opposition to the spring 107 is effected by a stop pin 113, which serves to hold the valve member 100 against movement beyond registration of the groove 108 with the port 111 in the maximum rearward shifting of the valve member.

Operation of the modified pump unit 85 is substantially the same as operation of the pump unit 15. In the non-operating position of the pump unit, the modulator block 90 is in its position of maximum eccentricity relative to the rotor 94, under the influence of the priming spring 97. As soon as the pressure is built up within the pump after starting thereof, the influence of the high pressure in the forward end of the control chamber 101, acts upon the valve member 100 and when the rated mean pressure is attained, the valve member 100 is shifted to the neutral position wherein both of the pressure areas 91 and 92 are isolated and maintained in substantially dynamic fluid pressure balance to hold the modulator 90 against displacement.

Upon increase in the pump pressure beyond the rated mean pressure, immediate reaction of the valve member 100 causes it to move further against the spring 107 and effect communication of the pressure area 92 with the low pressure or suction side of the pump by way of the port 111 and as a result the modulator 90 is shifted to reduce the pump displacement and the pressure promptly returns to the predetermined mean pressure output of the pump and the valve member 100 slides back to its neutral position wherein the modulator 90 is held substantially against displacement by the dynamic pressure fluid balance in the pressure areas 91 and 92. Should the pressure drop, the valve member 100 moves to effect registration of the groove 108 with the port 109 and the modulator 90 shifts to increase the fluid displacement of the pump. This process continues automatically as long as the pump is in operation. The mean pressure for which the pump is rated is thus maintained smoothly and continuously.

Should the fluid demand cease abruptly, the valve member 100 can respond instantly to move to its limit against the pin 113 and thus cause the modulator 90 to shift to its concentric limit relative to the rotor 94 to relieve any tendency to overload the pump. Then as the pump continues in operation only such limited displace-

ment will prevail automatically as will maintain the rated pressure until there is again a fluid demand and the pump responds with unusually small initial pressure drop.

The modification shown schematically in Figures 11, 12 and 13, depicts a control arrangement that is applicable as an alternative for the control arrangement disclosed in connection with either of the pump units 15 or 36. The principal difference resides in the control of high pressure fluid to the pressure areas at opposite sides of the modulator block by the control valve. This may be effected in addition to the direct communication of the pressure areas with the high pressure side of the pump or as an alternative to such direct communication. Accordingly, main pump body block B has modulator block M slidable therein and with pressure areas P¹ and P² at the opposite ends of the modulator block. Where direct communication of the pressure areas with the pump chamber is desired, the pressure areas may be maintained in somewhat restricted though constant high pressure communication with the high pressure side of the pump by passageway or duct D, corresponding substantially to the previously described duct 41 in Figure 3. As an alternative, or in addition, a duct DD may be provided which affords restricted direct communication between the pressure area chambers P¹ and P².

Valve unit V comprises a reciprocable plug type valve body 115 having a pair of axially spaced peripheral grooves 117 and 118 and is normally biased to one limit position by a spring 119. In this position of the valve body 115, high pressure fluid is conducted by way of a duct 120 from discharge port HP to the front end of control chamber 121 whence the high pressure fluid passes through the adjacent end of the valve body 115 through a duct 122 and by way of the groove 117 into a branch 123 of a high pressure fluid duct 124 that leads to the pressure area P².

In the initial or starting condition of the pump, a bleed-off duct 125 for effecting communication between the pressure area P¹ and the groove 118 in the valve member 115 is blocked by means such as an end spacer portion 126 on the modulator M. From the groove 118 leads a passage 127 through the rear end of the valve member 115 for communication past the spring 119 and through a duct 128 with the low pressure side of the pump at the inlet or low pressure port LP. Any tendency toward reduction in displacement of the pump before attaining rated pressure is controlled by opening of the bleed-off duct 125.

As the pressure mounts toward the rated pressure of the pump, which is predetermined by the load capacity of the spring 119, the valve member 115 is shifted by spring-compressing thrust of the high pressure fluid on the end thereof opposite the spring 119 until the grooves 117 and 118 are displaced to cut-off position relative to the openings to the ducts 123 and 125. In this condition, the modulator block M is held substantially in dynamic pressure balance against displacement, as shown in Figure 12.

Should the pressure increase beyond the predetermined mean pressure rating of the pump, the valve member 115 is shifted by force of the high pressure fluid on the end thereof opposite to the spring 119 and the spring yields until the condition shown in Figure 13 is attained wherein the high pressure groove 117 moves toward or into registration with a duct branch 129 of the

duct 125 so that high pressure fluid passes to the pressure area P¹. At the same time the groove 118 moves toward or into registration with a duct branch 130 of the duct 124 and thus opens the pressure area P² to the low pressure or suction side of the pump, shifting the modulator M to the extent required to modify the pump displacement and return the pressure to the rated mean. Thus, the valve member 115 will shift reciprocally from the neutral position of Figure 12 toward and into the positions of Figures 11 and 13 as demanded by tendency toward pressure fluctuations whereby to shift the modulator M selectively for controlling the pump displacement for maintaining the constant mean pressure desired.

Throughout the operation of the pump, fluid from the high pressure side of the pump is delivered equally by passageway D to the pressure areas or chambers P¹ and P² and/or the duct DD affords direct pressure communication between the chambers, so that in a sense both chambers are at all times pressure primed. As a result, operation of the valve controlled pump modifying system is rendered more quickly responsive, especially in rapid changes in volume demands upon the pump.

In order to assure that the modulator block M will not remain in neutral position when the pump is stopped, a priming spring 131 is preferably interposed between the end of the block and the opposing wall of the pressure area P², such spring herein comprising a leaf spring, although a coiled compression spring as in Figures 3 and 9 could be substituted.

The manner in which the control arrangement of Figure 11 may be adapted to the pumps 15 and 36 will be readily apparent. Whether the pressure passages or ducts D and DD will be used at all, or used separately, or together, will substantially depend in any specific pump unit upon numerous factors, including the size, weight or proportions of the various elements of the pump.

It will, of course, be understood that various details of construction may be varied through a wide range without departing from the principles of this invention, and it is, therefore, not the purpose to limit the patent granted hereon otherwise than necessitated by the scope of the appended claims.

We claim as our invention:

1. In a constant pressure variable displacement pump, means defining a modulator chamber, a modulator movable therein and defining with the walls defining the chamber fluid sub-chambers separated by the modulator, the modulator having a circular pump chamber therein, a rotary impeller on a fixed axis operating in said pump chamber and having impelling means co-operative with the annular wall defining the pump chamber to vary the pump displacement as the modulator moves in said first mentioned chamber, low pressure and high pressure ports respectively communicating with low pressure and high pressure sides of the pump chamber, a reciprocable plunger valve, a fluid passage communicating with the head of the valve and with the high pressure side of the pump chamber and normally exposing the head of the valve to pressure created by the pump, a spring operating against the opposite end of said valve and normally biasing the valve to resist movement of the valve responsive to the pump pressure with predetermined force, a fluid passage communicating with the low pressure side of the pump, and re-

spective fluid passages communicating with said sub-chambers, said plunger valve controlling said low pressure and said sub-chamber fluid passages and in its maximum spring biased position effecting communication between the low pressure fluid passage and the passage from one of said sub-chambers to assure displacement of the modulator into said one sub-chamber, the valve being movable by pump-created pressure in excess of the spring bias to effect communication between the fluid passage from said one sub-chamber and the high pressure fluid passage from the pump and coincidentally effect communication between the low pressure passage and the passage from the remaining sub-chamber whereby to cause shifting of the modulator toward or into said remaining sub-chamber.

2. In a constant pressure variable displacement pump, means defining a modulator chamber, a modulator movable therein and defining with the walls defining the chamber fluid sub-chambers separated by the modulator, the modulator having a circular pump chamber therein, a rotary impeller on a fixed axis operating in said pump chamber and having impelling means cooperative with the annular wall defining the pump chamber to vary the pump displacement as the modulator moves in said first mentioned chamber, low pressure and high pressure ports respectively communicating with low pressure and high pressure sides of the pump chamber, a reciprocable plunger valve, a fluid passage communicating with the head of the valve and with the high pressure side of the pump chamber and normally exposing the head of the valve to pressure created by the pump, a spring operating against the opposite end of said valve and normally biasing the valve to resist movement of the valve responsive to the pump pressure with predetermined force, a fluid passage communicating with the low pressure side of the pump, and respective fluid passages communicating with said sub-chambers, said plunger valve controlling said low pressure and said sub-chamber fluid passages and in its maximum spring biased position effecting communication between the low pressure fluid passage and the passage from one of said sub-chambers to assure displacement of the modulator into said one sub-chamber, the valve being movable by pump-created pressure in excess of the spring bias to effect communication between the fluid passage from said one sub-chamber and the high pressure fluid passage from the pump and coincidentally effect communication between the low pressure passage and the passage from the remaining sub-chamber whereby to cause shifting of the modulator toward or into said remaining sub-chamber, said valve being carried entirely by the modulator and all of said fluid passages being in said modulator.

3. In a constant pressure variable displacement pump, means defining a modulator chamber, a modulator movable therein and defining with the walls defining the chamber fluid sub-chambers separated by the modulator, the modulator having a circular pump chamber therein, a rotary impeller on a fixed axis operating in said pump chamber and having impelling means cooperative with the annular wall defining the pump chamber to vary the pump displacement as the modulator moves in said first mentioned chamber, low pressure and high pressure ports respectively communicating with low pressure and high pressure sides of the pump chamber, a reciprocable plunger valve, a fluid passage communicating

with the head of the valve and with the high pressure side of the pump chamber and normally exposing the head of the valve to pressure created by the pump, a spring operating against the opposite end of said valve and normally biasing the valve to resist movement of the valve responsive to the pump pressure with predetermined force, a fluid passage communicating with the low pressure side of the pump, and respective fluid passages communicating with said sub-chambers, said plunger valve controlling said low pressure and said sub-chamber fluid passages and in its maximum spring biased position effecting communication between the low pressure fluid passage and the passage from one of said sub-chambers to assure displacement of the modulator into said one sub-chamber, the valve being movable by pump-created pressure in excess of the spring bias to effect communication between the fluid passage from said one sub-chamber and the high pressure fluid passage from the pump and coincidentally effect communication between the low pressure passage and the passage from the remaining sub-chamber whereby to cause shifting of the modulator toward or into said remaining sub-chamber, said valve being carried by said means defining the modulator chamber and said fluid passages also being in said means.

4. In combination in a constant pressure variable displacement pump, means defining a casing having a modulator chamber therein, a modulator member in said chamber and dividing the chamber into fluid areas at opposite sides of the modulator and into which areas the modulator is alternately movable, the modulator having a circular pump chamber therein, a pump rotor operable on a fixed axis in said pump chamber and having means cooperating with the wall defining the pump chamber for variable fluid displacement, the wall of the casing opposing one face of the modulator having a duct therein communicating with the high pressure side of the pump chamber and having ports at its opposite ends communicating with the respective fluid areas, and respective check valves at said ports permitting flow of fluid from the pressure side of the pump into said areas but blocking return flow of fluid.

5. In combination in a constant pressure variable displacement pump construction, means defining a modulator chamber, a modulator movable in said chamber and cooperating with the walls of the chamber to define fluid pressure areas at opposite sides of the modulator into which the modulator is movable, the modulator having a circular pump chamber therein, a fixed axis rotor in said pump chamber having means cooperating with the annular wall defining the pump chamber to effect variable fluid displacement as modified by the modulator moving in said modulator chamber, fluid passages extending from the respective fluid pressure areas, a fluid passage extending from the high pressure side of the pump, a fluid passage extending to a low pressure source, means defining a valve chamber, a valve member movable in said chamber, all of said passages communicating with said valve chamber, and means acting against one side of the valve member to bias the valve member normally in one direction, the fluid passage from the high pressure side of the pump communicating with the opposite side of the valve member and normally acting to move it in opposition to said biasing means, passages in said valve member affording communication selec-

tively between said low and high pressure passages and said pressure area passages and being arranged to effect communication between the high pressure passage and one of said pressure area passages in the fully biased position of the valve member while at the same time effecting communication between the low pressure passage and the remaining pressure area passage, and alternating the connection between the respective pressure area passages and the low and high pressure passages when the valve member is moved in opposition to said biasing means by pump created pressure.

6. In combination in a variable displacement pump including a housing having therein a modulator chamber, a modulator member having a pump chamber therein and being narrower than said modulator chamber on one transverse axis through said chamber, means on the modulator and on the housing within said modulator chamber and disposed on an axis transverse to said first mentioned axis and cooperating to provide a substantial pressure fluid seal between the modulator and the housing to divide the areas of the modulator chamber through which said first mentioned axis extends into sub-chambers to which respective opposite peripheral areas of the modulator are directly exposed, a fixed axis pump rotor in said pump chamber and having means cooperating with the wall defining said pump chamber to effect variable fluid displacement as modified by the modulator movable in said modulator chamber, means defining a restricted pressure bleed passage between the high pressure side of the pump and each of said subchambers, and control means providing a pressure passage communicating with the high pressure side of the pump chamber and respective separate passages communicating with said sub-chambers, a low pressure passage, said control means also providing a valve chamber with which all of said passages communicate, a valve member in said valve chamber and responsive to pump created pressure delivered thereto by said pressure passage for controlling said separate passages for subjecting said sub-chambers automatically and selectively to said low pressure passage for determining the relation of the modulator to said pump rotor and thereby determining displacement of the pump.

7. A variable displacement pump as defined in claim 6, including in addition means in said one sub-chamber normally biasing the modulator into maximum displacement relation to the pump rotor in order to assure full pump displacement at the beginning of operation.

8. In combination in a variable displacement pump construction, means defining a modulator chamber, a modulator operable shiftably in said chamber and defining in said chamber opposite sub-chambers to which opposite peripheral surfaces of the modulator are constantly exposed, the modulator having a pump chamber therein, a fixed axis pump rotor operable in said pump chamber and having means cooperable in fluid displacement relation with the wall defining said pump chamber, the modulator being movable in said modulator chamber relative to said rotor to determine the pump displacement, means within the confines of said modulator-chamber-defining means including a valve chamber and passages communicating between said valve chamber and said sub-chambers and said pump chamber, and a valve in said valve chamber having means affording communication se-

lectively between said pump chamber and said passages communicating with the sub-chambers, said valve being operative automatically in response to pump created pressures communicated thereto by said passage communicating with the pump chamber whereby to vary the position of the valve relative to said passages communicating with the sub-chambers to control the communication of said communication means with these passages and thereby to control the position of the modulator relative to the pump rotor by subjecting the exposed areas of the modulator periphery within said sub-chambers to variable pump pressures, and restricted flow area pressure bleed passage means effecting communication between the high pressure portion of the pump chamber and at least one of said sub-chambers in addition to and independent of said control means.

9. In combination in a constant pressure variable displacement pump, means defining a casing having a modulator chamber therein, a modulator member in said chamber and dividing the chamber into fluid areas at opposite sides of the modulator and into which areas the modulator is alternately movable, the modulator having a circular pump chamber therein, a pump rotor operable on a fixed axis in said pump chamber and having means cooperating with the wall defining the pump chamber for variable fluid displacement, the wall of the casing opposing one face of the modulator having a bleed duct therein communicating with the high pressure side of the pump chamber and having its opposite end portions communicating with the respective fluid areas for subjecting said areas to dynamic balance of pump pressure during operation, and means for establishing communication between a low pressure source and any one of said fluid areas selectively to effect a pressure unbalance between the fluid areas to thus shift the modulator for varying the fluid displacement of the pump.

10. In combination in a constant pressure variable displacement pump, a housing structure defining a modulator chamber, a modulator structure adjustably movable in said chamber, the modulator structure having oppositely directed surface portions cooperative with portions of said housing structure to define respective fluid pressure sub-chambers into and out of which said surface portions are alternately selectively movable responsive to pressure differentials in said sub-chambers for thereby adjustably moving the modulator structure, said modulator structure having a pump chamber therein, a rotor mounted on a fixed axis with respect to said housing structure and operable in said pump chamber, said rotor having means cooperating with the wall defining the pump chamber to effect variable fluid displacement as modified by the modulator structure as adjustably positioned in said modulator chamber, said housing structure providing fluid supply and fluid discharge ports communicating respectively with the low and high pressure side of said pump chamber, one of said structures providing a valve chamber, a valve movably mounted in said valve chamber, a fluid passage connecting the high pressure side of the pump chamber with said valve chamber in such relation to said valve as to impress upon the valve pump-created high pressure to move the valve automatically in one direction during operation of the pump, means normally biasing the valve in the opposite direction in opposition to the

pump pressure impressed thereon, a low pressure exhaust passage leading from said valve chamber, respective communication passages connecting said sub-chambers with said valve chamber, said valve being operable to effect communication with one of said communication passages and said exhaust passage in the maximum biased position of the valve effected by said biasing means, said valve being movable in said one direction by pump pressure in excess of a predetermined biasing value of said biasing means to close said one communication passage and open the other communication passage to said exhaust passage, while during pump created pressure substantially balancing said predetermined value of the biasing means the valve assumes a position blocking communication between both of said communicating passages and said exhaust passage, and passage means connecting the high pressure side of the pump chamber and said sub-chambers for pressure priming said sub-chambers and also for maintaining said sub-chambers in substantially pressure balanced relation in the positions of the valve wherein both of said communicating passages are blocked from said exhaust passage, said valve reacting automatically to dynamic pressure variations from a mean pump pressure determined by the predetermined biasing force of said biasing means for controlling the pressure in said sub-chambers by controlling said communicating passages with respect to said exhaust passage as aforesaid.

11. A combination as defined in claim 10, wherein the passage means connecting the sub-chambers and the high pressure side of the pump

chamber comprises a duct independent of said valve chamber.

12. A combination as defined in claim 10, wherein the passage means connecting the high pressure side of the pump chamber and said sub-chambers comprises a high pressure passage leading from the valve chamber and controlled by the valve and communicating with one of said sub-chambers and a further passage connects the sub-chambers together for high pressure balance.

13. A combination as defined in claim 10, wherein the passage means connecting the high pressure side of the pump chamber with said sub-chambers comprises respective high pressure ducts under the control of said valve and leading from said valve chamber to said sub-chambers respectively.

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