March 24, 1959 B. E. O'CONNOR ET AL 2,878,755

VARIABLE DISPLACEMENT PUMP AND PRESSURE RESPONSIVE CONTROL MEANS THEREFOR

Filed May 13, 1950

2 Sheets-Sheet 1

Fig. 2

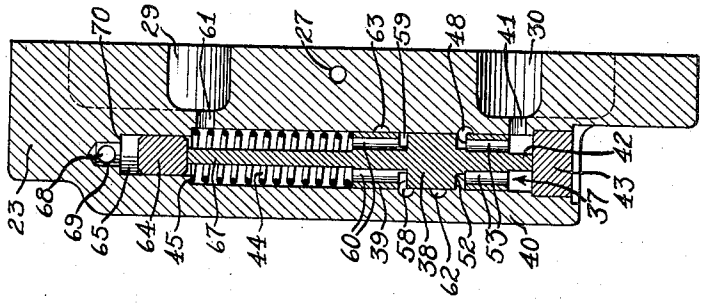

Fig. 1

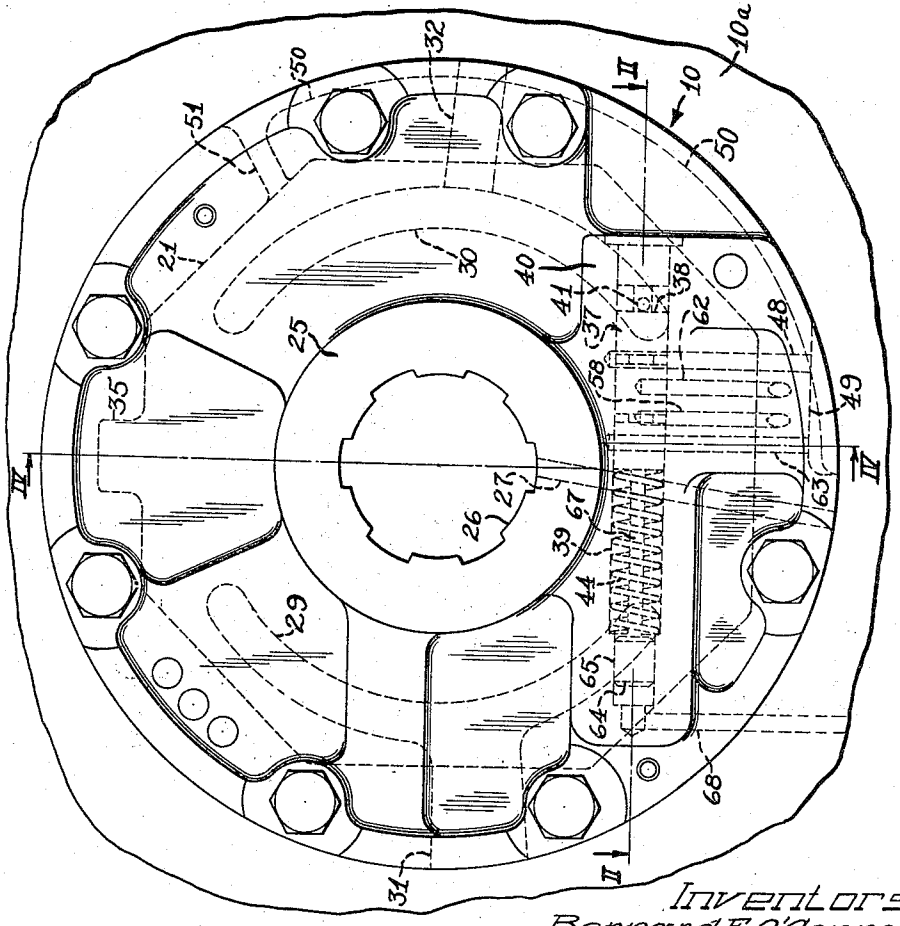

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Fig. 4

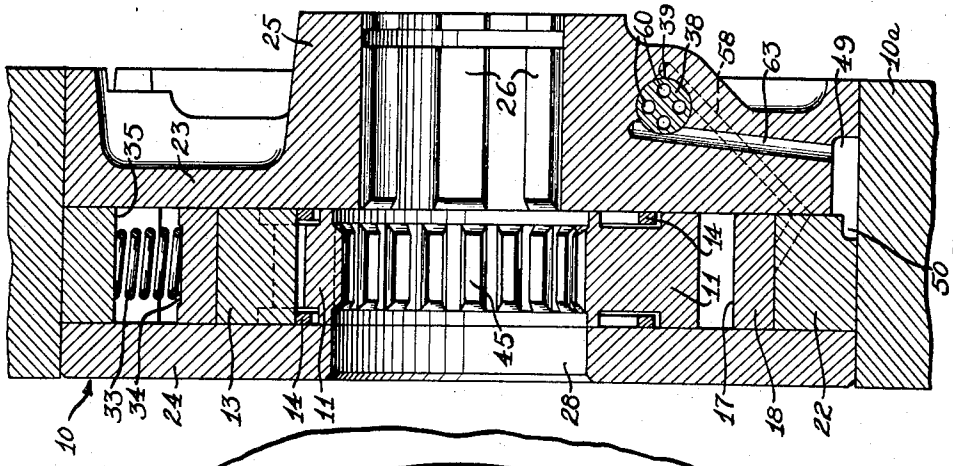
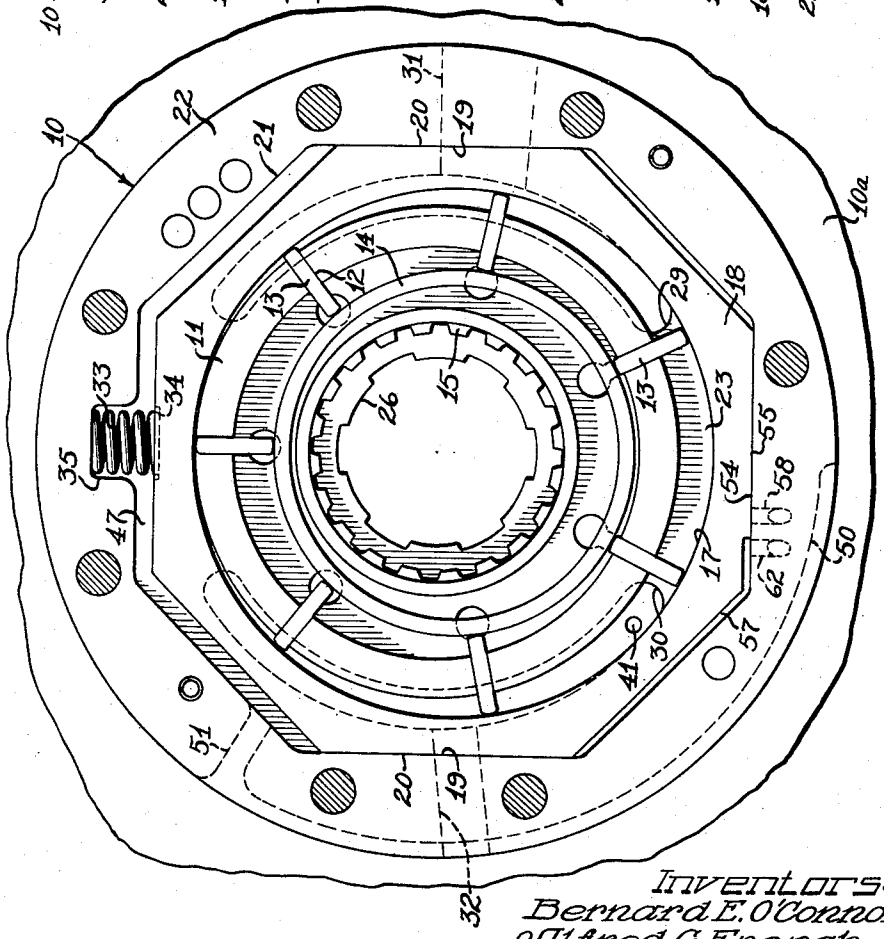


Fig. 3



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VARIABLE DISPLACEMENT PUMP AND PRESSURE RESPONSIVE CONTROL MEANS THEREFOR

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Application May 13, 1950, Serial No. 161,754

5 Claims. (Cl. 103—120)

The present invention relates to improvements in variable displacement pumps and is more particularly concerned with novel structure and relationships in such pumps for controlling pump displacement.

An important object of the present invention is to provide improvements in variable displacement pumps for automatically as well as selectively adjusting pump displacement.

Another object of the invention is to provide improved means for controlling variable displacement pumps responsive to pump-created pressure and selectively adjustable for varying the pump pressure responsiveness thereof.

A further object of the invention is to provide novel pressure responsive control valve means and means for selective modification of its pressure responsiveness for controlling the displacement of a variable displacement pump.

Yet another object of the invention is to provide improved control valve means for variable displacement pumps normally responsive to predetermined pump-created pressure above a mean pressure to maintain the pressure substantially constant by varying the pump displacement, and including means controllable from a point externally of the pump to vary the pressure responsiveness of the valve means.

Still another object of the invention is to improve the general construction of variable displacement pumps.

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

Figure 1 is an elevational view of one side of a variable displacement pump of a type especially suitable for use in a transmission for an automotive vehicle or the like;

Figure 2 is a sectional detail view taken substantially on the line II—II of Figure 1 through the face plate of the pump assembly shown in full in Figure 1;

Figure 3 is a side elevational view of the opposite side of the pump from that shown in Figure 1 and with the face plate removed to reveal internal mechanism of the pump; and

Figure 4 is a sectional detail view taken on substantially the line IV—IV of Figure 1.

By way of illustration there is shown in the drawings a variable displacement pump of the sliding vane type and in the particular embodiment shown adapted for use in the transmission system of an automotive vehicle. The pump comprises a casing **10** housing a pump rotor **11** which has a uniformly spaced series of radial peripherally opening slots **12** within which are operably disposed sliding reciprocable vanes **13**. The sides of the rotor **11** are inset at predetermined distance from its periphery at both sides to accommodate concentric rings **14** in engagement with the inner ends of the vanes **13** and functioning to maintain the outer ends of the vanes or blades on a predetermined diameter. A central bore may be provided through the rotor **11** provided with spline teeth **15** by which the rotor is adapted to be assembled for rotation upon a splined shaft in a transmission assembly.

A circular pump chamber **17** concentric with the control rings **14** and of a diameter to be constantly engaged by the outer tips of the vanes **13** is provided by a displacement control member or modulator **18**. In the present instance the modulator **18** is of the reciprocably guided type having opposite parallel flat sides or edges **19** slidably engaging parallel bearing walls **20** defining opposite sides of a modulator control chamber **21** provided in an intermediate casing member or ring **22**. By preference the housing ring **22**, the modulator **18** and the rotor **11** are of approximately the same thickness, that is their broad faces are disposed in approximately the same planes while opposite facing plates **23** and **24** complete the housing or casing **10** enclosing the pump and more particularly affording closures for the pump chamber **17** and the modulator chamber **21**. In assembly, sufficient sliding clearance is afforded for the pump rotor **11** and the modulator **18** after the facing plates **23** and **24** have been secured to the opposite faces of the intermediate casing member **22** so as to permit free rotation of the rotor **11** and slidable reciprocation of the modulator ring **18**.

As best seen in Figure 4, the facing plate **23** may be provided with a central hollow hub **25** provided with internal splines **26** for connection of a spline member in the transmission with which the unit may be used. A fluid passage **27** leads from the splined bore to the outside of the casing. The diameter of the spline bore in the boss **25** may be smaller than the diameter of the spline bore in the pump rotor **11**. Clearance passage for the shaft to which the pump rotor is splined is provided by a concentric bore **28** in the facing plate **24**.

Rotation of the rotor **11** in operation is intended to be clockwise as viewed in Figure 3 so that hydraulic fluid from any appropriate source is drawn through an arcuate inlet duct or port **29** by action of the rotor blades **13** at the low pressure side of the pump and displaced through an outlet duct or port **30** at the high pressure side of the pump. Both of the ports **29** and **30** are preferably located in the inner face of the facing plate **23**. As best seen in Fig. 1, an inlet passage **31** leads to the inlet port **29** while a discharge or high pressure passage **32** leads from the high pressure port **30**.

At the beginning of operation, at least, it is desirable that the pump displacement be at maximum, and for this purpose the modulator **18** is preferably biased to dispose the pump chamber **17** in maximum eccentric pumping relation to the rotor **11** by a spring **33** which may be in the form of a coiled compression biasing spring seated at one end in a shallow depression **34** in one end of the modulator and at its other end in a socket-like recess **35** in the opposing wall defining the modulator chamber **21** in the intermediate casing ring **22**.

The principal function of the biasing spring **33**, which may be of relatively light weight and which need not be of any critical load or compression strength, is to assure that the modulator **18** will normally be, at least at the beginning of operation, in a position of pump chamber eccentricity with respect to the pump rotor **11**. As a result, when the pump is started, maximum displacement will occur.

Means are provided for automatically adjusting the modulator **18** to vary displacement of the pump in operation to maintain predetermined mean output pump pressures throughout a selective range. This is accomplished by the provision of a pump-pressure-responsive, automatically adjustable control valve structure **37** (Figs. 1 and 2) operable to control the application of pump-

created pressure for directly adjusting the position of the modulator 18 within the modulator chamber 21 for establishing and maintaining such a relationship of the pump chamber 17 to the pump rotor 11 that a mean pump output pressure selected within a variable range is maintained as desired.

In a convenient, economical and highly efficient form the control valve assembly 37 includes a reciprocable plunger valve member 38 operatively slidably disposed within a bore 39 in the pump housing 10, and in the present instance located in the facing plate 23 which for this purpose is provided with a thickened portion or embossment 40 at one side of the hub 25. A salient advantage of such location of the valve bore 39 resides in that all piping can be avoided for effecting communication between the fluid system of the pump and the modulator chamber 21 by way of the control valve. All such communication can thus be effected by passages or ducts in the housing 10. This is a valuable feature where space is at a premium and a compact unit without external ducts, tubes or piping is desired, such as in an automotive transmission. This arrangement also avoids the liability of accidental blockage or restriction of the intercommunicating fluid passages as often occurs in systems including tubes serving as fluid passages and thus liable to damage during installation or servicing of the apparatus, or otherwise. Furthermore, frictional pressure losses are greatly reduced because of the relatively more direct, short passage communications that can be attained through the ducts and bores providing fluid passage within the walls of the housing 10.

By preference, the control valve housing bore 39 is so disposed that direct communication with the high pressure or discharge port 30 of the pump is effective through a passage bore 41 between the port 30 and one end portion of the valve bore 39. In this way the adjacent end of the valve body 38 is subjected to pump pressure during operation. In order to assure constant exposure of the mentioned end of the valve member to the high pressure, such end may be provided with a reduced diameter or head end stop finger 42 engageable with a closure plug 43 by which the proximate end of the valve bore 39 is sealed off outwardly from the high pressure communication duct 41.

The valve member 38 is normally biased in opposition to pump pressure, that is toward the head end of the valve, by means herein comprising a coiled compression spring 44 acting against the opposite or rear end of the valve member and seated against a bottom or shoulder 45 at the inner end of the valve bore. For this purpose, the length of the valve housing bore 39 is substantially longer than the body portion of the valve member 38. The spring 44 is selected both as to length and tensioning qualities to resist, under load, movement of the valve member 38 in opposition to the spring with a predetermined static force. Thus, until the dynamic pressure of the pump-impelled fluid attains a force in excess of the spring loading, the valve 38 will be maintained in its fully biased position.

The relationship of the biasing spring 44 to the valve member 38 is such that when a mean pump output pressure value is exceeded, the pump pressure acting upon the head of the valve drives the valve in opposition to the spring for effecting valve controlled communication with the modulator chamber 21 to effect shifting of the modulator and thus adjustment in the pump displacement and return to the mean output pressure. For this purpose, communication is effected between appropriate portions of the valve bore 39 and the modulator chamber 21. Since during acceleration of the pump at the beginning of operation or during operation at lower than the mean output pressure, it is desirable to have the modulator 18 in the position of maximum pump chamber eccentricity relative to the pump rotor 11, initial communication between a sub-chamber 47 between the end of the modulator 18 engaged by the biasing spring 33 and the opposing wall defining the modulator chamber is effected with the high pressure side of the pump by way of a port or duct 48 (Figs. 1, 2 and 4) leading from the valve bore 39 to a recess 49 in the periphery of the facing plate 23 and communicating with a fluid passage channel 50 provided in the periphery of the intermediate housing member 22 running to a radially inwardly directed passage 51 entering the modulator sub-chamber 47. A housing member 10a about the casing 10 closes the recess 49 and the channel 50. In the fully biased or at rest position of the valve member 38 an annular groove 52 in the valve member registers with the passage 48, while a plurality of annularly spaced longitudinally extending bores 53 in the head end portion of the valve member afford communication between the head end of the valve member and the channel 52. Thus, pump-created pressure less than and up to the mean pressure for which the valve member 38 is biased will be effected through the communication passageway to the modulator sub-chamber 47 for acting on that end, namely the biased end of the modulator to assist the biasing spring 33 in maintaining the modulator in full eccentric position.

At the same time, all pressure is relieved from the opposite end of the modulator 18. At this end, the modulator is formed with a flattened stop portion 54 which engages a complementary flattened abutment portion 55 defining part of the wall of the modulator chamber in the intermediate casing member 22 (Fig. 3). Adjacent the stop portion 54, the end portion of the modulator is recessed or set back to provide a modulator sub-chamber 57. A bore passage 58 communicates with the sub-chamber 57 and with the valve bore 39 in a position to register with a peripheral annular communication groove 59 in the valve member 38 communicating by way of an annularly spaced set of longitudinal passages 60 with and through the end of the valve member 38 and thus with the biasing spring chamber in the bore 39 behind the valve member. A port 61 effects communication between the inner end portion of the valve chamber 39 and the low pressure or suction port 29 of the pump fluid system. Thus, means are provided in an efficient and simple manner for relieving the modulator of pressure at the end toward which it is biased while the pump is operating below a given mean operating pressure. It will be understood, of course, that preferred communication could be effected between the sub-chamber 57 and atmosphere at a sump or the like, since the principal consideration is pressure relief.

When the pump-created pressure has attained the desired mean the valve member 38 is moved in opposition to the biasing spring 44 to a balanced position wherein the valve member 38 closes off the ports or passages 48 and 58. This substantially locks the modulator 18 in its fully eccentric position.

Upon development of pump pressure in excess of the mean pressure desired, the valve member 38 is moved additionally in opposition to the biasing spring 44 until a pressure fluid duct or port 62, which up to this time has been closed by the valve 38, is opened to the high pressure side of the pump by registration of the high pressure groove 52 in the valve with the port 62. The pressure port or passage 62 communicates with the modulator sub-chamber 57 to exert pressure upon the contiguous end of the modulator 18 and shift the modulator toward a position of less pump chamber eccentricity relative to the rotor 11. At the same time pressure relief communication with the modulator sub-chamber 47 is effected by opening of a port or passage 63 upon registration of relief groove 59 in the valve member therewith to effect communication with the recess 49 to which the passage 63 leads. Thus, the modulator is quickly shifted and the desired mean output pressure re-established, the valve member 38 returning to a port blocking position

as soon as the desired mean pressure has been re-established.

It will thus be apparent that highly sensitive control automatically in response to pump-created pressure is afforded over the modulator 18 by response of the valve 38 to action of the biasing spring 44 and the dynamic pressure of the pump acting upon respective opposite ends of the valve member.

To accommodate situations where in the course of operation it is necessary to increase the mean pump output pressure during any particular interval, means are provided for selectively imposing an increased biasing pressure upon the valve member 38 in addition to and supplemental to the biasing spring 44. To this end, a supplementary biasing plunger element or member 64 is slidably disposed within a reduced diameter inward extension 65 from the valve bore 39 and concentric with the valve bore. Valve biasing engagement with the valve member 38 by the biasing plunger 64 is effected through the medium of a rearwardly extending projection or stem 67 on the valve member directed into the spring 44.

When the control valve 38 is to function solely under the biasing influence of the spring 44, the auxiliary biasing plunger 64 remains inert or free floating in the bore extension 65. However, when it is desired to increase the bias upon the valve 38, fluid under pressure is introduced into the bore portion 65 through a passage 68 leading into a further reduced diameter portion or port 69 at the rear of the reduced bore portion 65. The passage 68 leads off through the casing face plate 23 and if desired on through the outer housing or supporting member 10*a* and communicates with any preferred source of fluid under pressure which may be a separate source of fluid or may be the pressure fluid displaced by the pump. In any event, any preferred additional biasing load may be imposed upon the valve 38 by the fluid pressure introduced behind the biasing plunger 64. For example, if the biasing spring 44 is rated at a loading of thirty pounds per square inch resistance to the valve 38, and it is desired to establish a mean pump output pressure of sixty pounds per square inch, then the pressure introduced behind the biasing plunger 64 will be sixty pounds per square inch. Of course, it will be clear that any other selected or additional pressure desired may be imposed upon the valve 38 through the plunger 64 by imposing the desired auxiliary biasing fluid pressure upon the auxiliary biasing plunger 64.

The stem extension 67 of the valve member 38 also serves as a stop for limiting rearward or pressure induced movement of the valve member 38, so that under unusual pressure thrusts the valve member will not overrun the system of control ports leading to the modulator chamber. Accordingly, at the limit of pressure thrust movement of the valve member, the auxiliary plunger 64 comes to rest against a stop shoulder 70 provided at the bottom of the auxiliary reduced diameter auxiliary plunger bore 65. In this thrust limit position, of course, high pressure fluid from the pump will be conveyed by way of the passage 62 to the modulator sub-chamber 57 for driving the modulator toward a position of reduced pump chamber eccentricity.

From the foregoing it will be apparent that the present invention provides a variable displacement pump control arrangement that is not only highly sensitive for selective multi-stage pressure responsiveness within a large range, but also in any stage of selected or adjusted pressure responsiveness of the control valve mechanism is automatically adjustable for variable displacement of the pump to maintain a desired mean pumping pressure.

It will be understood that modifications and variations may be effected without departing from the scope of the novel concepts of the present invention.

We claim as our invention:

1. In combination in control means for a variable displacement pump, a casing having a bore, a control valve plunger in said bore and means for directly subjecting the valve plunger at one end to pressure fluid from the high pressure side of the pump, a spring in said bore operative on the valve plunger in opposition to the high pressure on the valve plunger, a stem projecting from the valve plunger past the spring, a reduced diameter portion at the rear end of the bore, an auxiliary pressure plunger in said reduced diameter portion, said stem being engageable by said auxiliary plunger, and means for introducing pressure fluid into said reduced diameter bore behind said auxiliary plunger for thrusting said auxiliary plunger against said stem and thereby supplementing the bias of said spring.

2. In combination in control means for a variable displacement pump, a casing having a bore, a control valve plunger in said bore and means for directly subjecting the valve plunger at one end to pressure fluid from the high pressure side of the pump, a spring in said bore operative on the valve plunger in opposition to the high pressure on the valve plunger, a stem projecting from the valve plunger past the spring, a reduced diameter portion at the rear end of the bore, an auxiliary pressure plunger in said reduced diameter portion, said stem being engageable by said auxiliary plunger, and means for introducing pressure fluid into said reduced diameter bore behind said auxiliary plunger for thrusting said auxiliary plunger against said stem and thereby supplementing the bias of said spring, said auxiliary bore having an inner generally axially facing shoulder against which the auxiliary plunger is engageable as a stop to limit movement of the valve plunger in opposition to the spring and auxiliary plunger.

3. In a variable displacement pump construction, a casing ring defining a modulator chamber, a modulator ring member in said chamber and cooperating at diametrically opposite sides with the wall of said ring defined chamber to divide the space in said chamber into opposite sub-chambers at respective diametrically opposite sides of the modulator between said first mentioned diametrically opposite sides, said modulator having therein a pump chamber within which a pump rotor and fluid impelling means are adapted to operate, casing structure enclosing the opposite faces of said casing ring and the periphery of said casing ring, respective fluid inlet and outlet ports communicating through said casing structure with the pump chamber, said casing structure having a valve chamber therein, said casing structure having a passage leading from one of said sub-chambers to said valve chamber, said casing ring and said casing structure having a fluid passage leading to said valve chamber from the other of said sub-chambers, said casing structure having a further passage leading to said valve chamber from said outlet port, and a valve member in said valve chamber responsive to fluid pressure through said further passage to control the flow of pressure fluid from said further passage through said valve chamber into selectively the passages from said sub-chambers, said passage leading from said other of said sub-chambers to said valve chamber comprising in part a groove in the outer periphery of said casing ring and said groove being closed at the periphery of the casing ring by the surrounding casing structure.

4. In combination in a variable displacement pump, a casing defining a modulator chamber, a modulator adjustably movable in said chamber and cooperating with the walls defining said chamber to divide the modulator chamber into sub-chambers at respectively substantially diametrically opposite ends of the modulator, the modulator having therein a pump chamber, a pump rotor operable in said pump chamber and having means cooperating with the wall of the modulator defining the chamber to displace fluid through the pump chamber, fluid inlet and outlet ports communicating with the pump chamber, and means for controlling the position of the modulator in said modulator chamber comprising: a valve chamber pro-

vided by the casing, respective passages leading from said sub-chambers to said valve chamber, a further passage leading from said outlet port to the valve chamber, a plunger valve reciprocable in said valve chamber and operable responsive to fluid pressure communicated through said further passage to control delivery of pressure fluid from said further passage through said valve chamber selectively to said passages that communicate with said sub-chambers, a spring normally biasing said valve plunger in opposition to the pressure of fluid delivered through said further passage, said valve plunger having a portion extending therefrom past the spring, a reciprocable plunger independent of the spring and reciprocable relative to the valve plunger but disposed in thrusting relation to said plunger, and means for subjecting the reciprocable plunger to fluid pressure to drive the reciprocable plunger into thrusting relation to said portion for supplementing the bias of the spring in opposing pressure from the pump through said further passage, whereby to increase the bias load that must be overcome before the valve plunger will shift in opposition to the spring.

5. In a variable displacement pump construction comprising a casing structure defining a modulator chamber having movable therein a modulator cooperating with the walls defining the chamber to divide the chamber into respective sub-chambers at substantially diametrically opposite ends of the modulator, the modulator having therein a pump chamber cooperative with a pump rotor for displacement of fluid through the pump chamber from an inlet port to an outlet port communicating with the pump chamber, the improvement which comprises: a reciprocable valve plunger, said casing having a valve chamber within which the valve plunger is reciprocable, respective passages in the casing communicating with an intermediate portion of the valve chamber, a pressure passage communicating with one end portion of the valve chamber and with the outlet port and impressing on one end portion of the valve pressure from the pump and for supplying pressure through said respective passages under the control of the valve plunger to said sub-chambers, additional passages leading from the valve chamber and communicating with said sub-chambers, a passage leading from the inlet port to the opposite end portion of the valve chamber for communication under the control of the valve plunger with said additional passages, a spring disposed between said opposite end portion of the valve chamber and the adjacent end portion of the valve normally biasing the valve toward said one end of the valve chamber, said opposite end of the valve chamber having a reduced diameter bore portion, a freely reciprocable biasing plunger in said reduced diameter portion, a stem on the valve adjacent to said biasing plunger and thrustingly engageable by the biasing plunger, and a passage leading into the inner end of said reduced diameter chamber portion for supplying fluid under pressure behind said biasing plunger to effect valve biasing thrust of said biasing plunger against said stem supplemental to the bias afforded by said spring.

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