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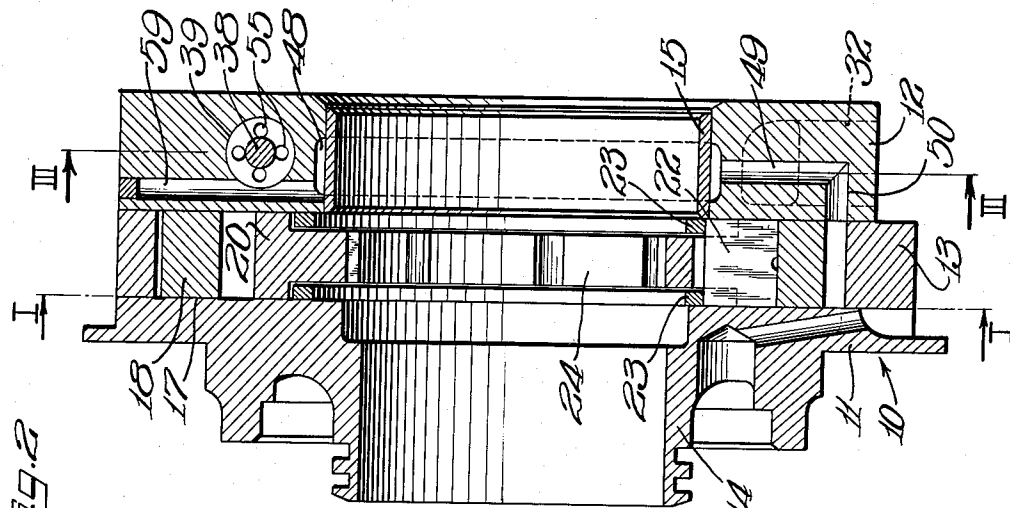
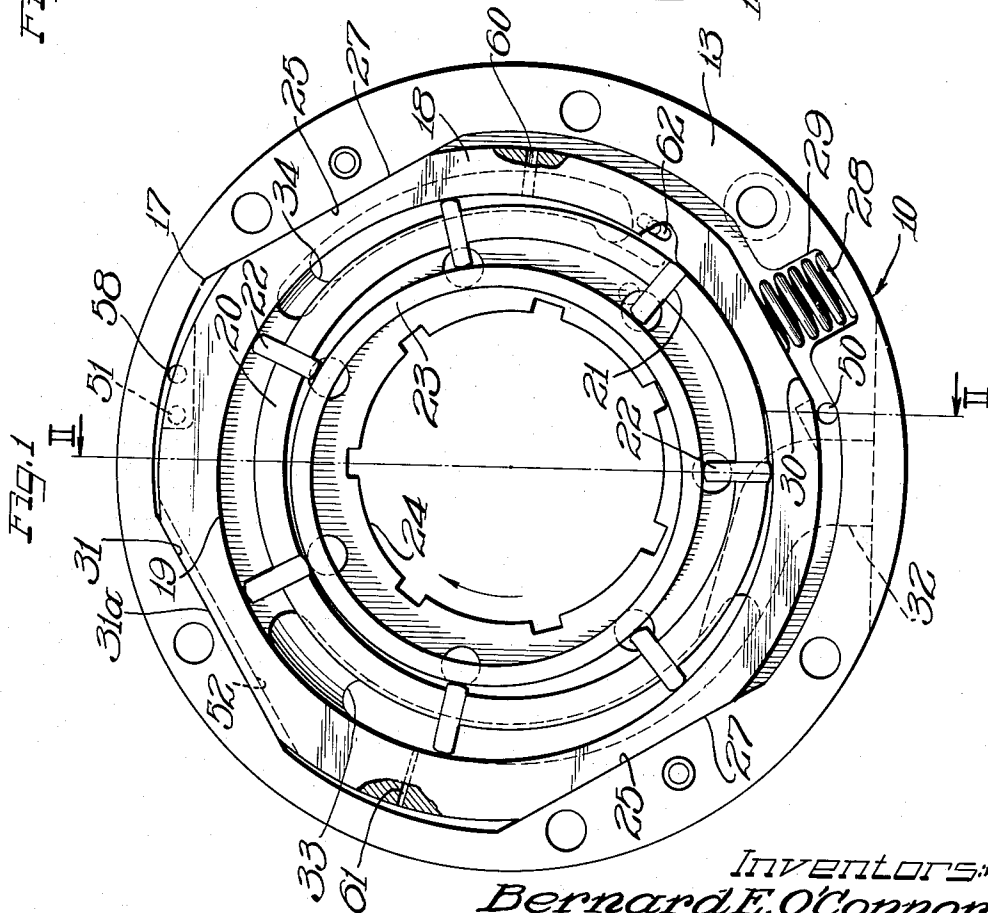
B. E. O'CONNOR ET AL

2,742,861

STABILIZED VARIABLE DISPLACEMENT PUMP

Filed Dec. 26, 1950

2 Sheets-Sheet 1



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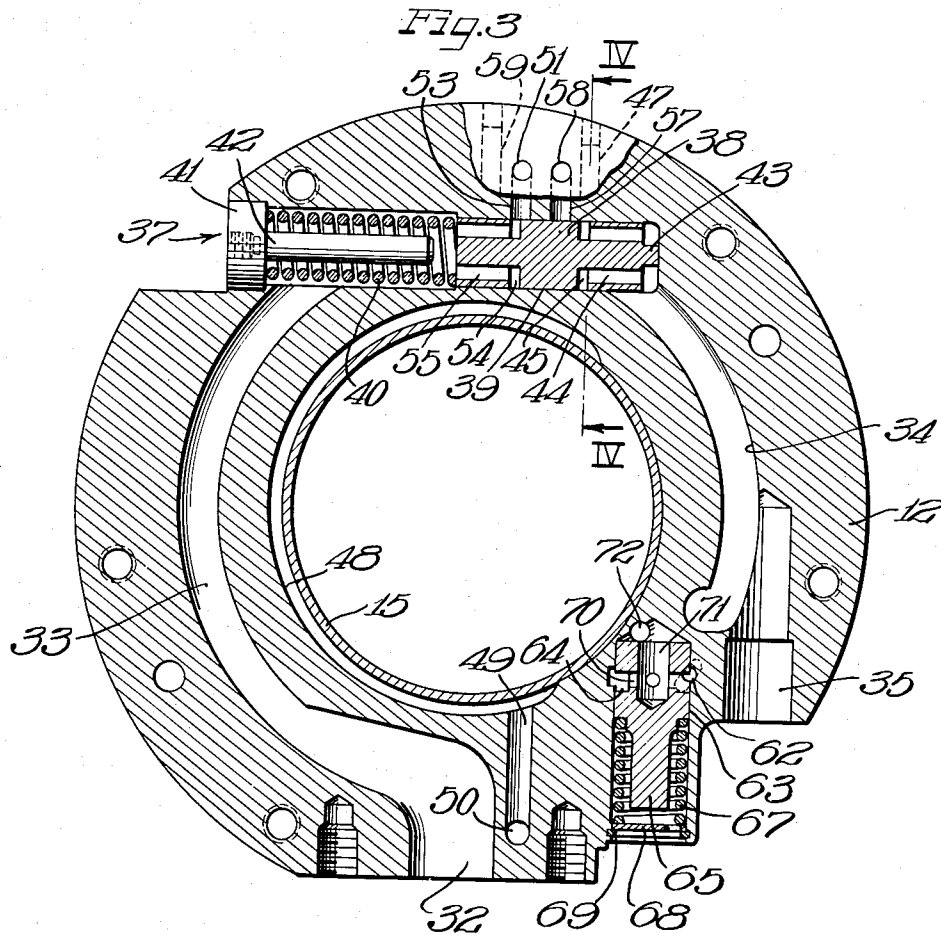
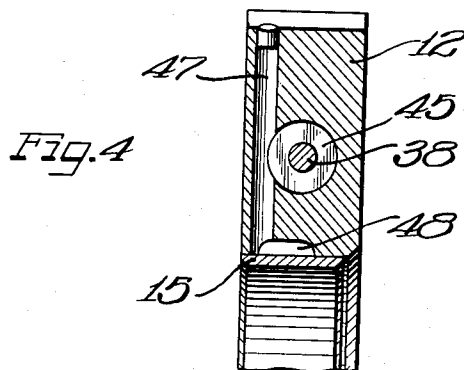
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1

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STABILIZED VARIABLE DISPLACEMENT PUMP

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7 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 stabilized control of pump displacement.

An important object of the present invention is to provide stabilizing means in automatically adjustable variable displacement pumps.

Another object is to provide means whereby a variable displacement pump is rendered self-stabilizing in operation.

A further object of the invention is to provide an automatically adjustable variable displacement pump having novel stabilizing means functioning automatically in the operation of the pump.

Still another object of the invention is to provide a variable displacement pump including novel means for diverting for lubrication or other uses fluid from the high pressure side of the pump under reduced pressure.

Yet 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 a face elevational view of a pump structure embodying the features of the invention, with the closure plate for said face removed so that the pump mechanism is viewed as though taken on the line I—I of Fig. 2;

Figure 2 is a vertical sectional view taken substantially on the irregular line II—II of Fig. 1;

Figure 3 is a transverse sectional view through the pump mechanism taken substantially on the line III—III of Fig. 2; and

Figure 4 is a fragmentary vertical sectional detail view taken substantially on the line IV—IV of Fig. 3.

In a variable displacement pump according to the present invention of a type which may be used in an automotive vehicle transmission assembly, a pump housing or casing 10 is provided by opposite face plates 11 and 12 which in assembly clampingly engage the opposite faces of an intermediate housing ring 13. The plate 11 has a central hollow boss 14 adapting the same for connection in the transmission with which the pump unit may be used, while the opposite face plate 12 has a coaxial central bore within which is fixedly mounted a bushing ring 15.

The intermediate housing ring 13 is of substantially larger internal diameter than the central bores or passages in the facing plates and thereby cooperates with the inner faces of the facing plates to provide a flattened chamber 17 within which is housed slidably a modulator ring member 18. A circular chamber 19 within the modulator ring accommodates a rotor 20 of smaller diameter than the chamber 19 and provided with a uniformly spaced series of radial slots 21 slidably accommodating radially projectable pumping vanes 22. The sides of the rotor 20 are inset at predetermined distance

2

from its periphery at both sides to accommodate concentric backing rings 23 in engagement with the inner ends of the vanes 22 and functioning to maintain the outer ends of the vanes or blades 22 on the predetermined diameter of and in engagement with the circular wall of the modulator ring 18 defining the pump chamber 19. For connecting the rotor to a driven spline shaft of the transmission assembly, a spline groove central bore 24 is provided in the rotor.

In the form shown, the modulator ring 18 is of the reciprocally slidable type movable reciprocally between a position of maximum pumping eccentricity of the pump chamber 19 relative to the rotor 20 to a concentric position. For this purpose, diametrically opposite sides of the modulator ring 18 are provided with parallel flat bearing edges 25 which are slidably engaged with parallel opposed respective bearing surfaces 27. The length of the modulator member 18 is somewhat less than the length of the modulator chamber 17 so that the modulator ring has a predetermined range of reciprocable movement as guided by the sliding bearings 25 and 27.

During the at rest condition of the pump, the modulator ring 18 is primed into one limit of reciprocal movement wherein maximum eccentricity of the rotor 20 within the pump chamber 19 is attained and for this purpose a coiled biasing spring 28 is seated in a cavity 29 in the housing ring 13 and opening toward a flattened end 30 of the ring. The biasing spring 28, priming the modulator 18 urges the modulator to engage with an opposite end flat 31 against a complementary flattened abutment 31a opposing the same at the opposite end of the modulator chamber 17 on the casing ring 13. Through this arrangement, when the rotor 20 revolves in the direction indicated by the directional arrow in Fig. 1, hydraulic fluid entering the casing through an inlet 32 in the facing plate 12 and entering the pump chamber 19 through an arcuate low pressure port 33 is driven by the rotor vanes 22 into a high pressure discharge port 34 arcuately disposed at the opposite side of the pump chamber 19 in the chamber face of the housing plate 12, whence the pumped fluid passes into a discharge port 35 to which may be connected a duct leading to mechanism to be driven by the high pressure fluid.

Means are provided for automatically adjusting the modulator 18 to vary displacement of the pump in operation to maintain a predetermined mean output pump pressure throughout a substantial range of pressure fluid requirements. To this end a pump-pressure-responsive, automatically adjustable control valve structure 37 (Fig. 3) is provided to control the application of pump-created pressure for directly adjusting the position of the modulator 18 within the modulator chamber 17 for maintaining such a relationship of the pump chamber 19 to the pump rotor 20 that the mean pump output pressure is substantially maintained.

In a convenient, economical and highly efficient form, the control valve assembly includes a reciprocable plunger valve 38 operatively slidably disposed within a bore 39 in the present instance provided in the housing plate 12 and in such a position that the bore communicates adjacent to its opposite ends with the respective adjacent ends of the low pressure and high pressure ports 33 and 34 respectively. The blind end of the bore 39 is preferably located at the high pressure port 34 while the entry end of the bore is located adjacent the low pressure port 33.

Means are provided for normally biasing the control valve plunger 38 toward the blind end of the bore 39. For this purpose, the valve plunger 38 is of substantially shorter length than the length of the bore 39 and a coiled compression biasing spring 40 is disposed to bear against the rear or outer end of the valve plunger while

at its opposite end the spring bears against a closure plug 41. A stop pin 42 carried by the closure plug has the distal end thereof in normally spaced relation to the adjacent end of the valve plunger to serve as a limit stop upon movement of the valve plunger toward the outer end of the valve bore. Through this arrangement, the forward end of the valve plug 38 is exposed to the high pressure side of the pump and the rear end of the valve plunger is exposed to the low pressure side of the pump, while the spring 40 biases the valve plunger with predetermined pressure toward the high pressure side.

While the control valve member 38 is in its maximum spring-biased position wherein an inner end or head stem 43 on the valve member maintains it in spaced relation to the blind end of the valve bore, fluid under pump pressure passes through a plurality of small diameter annularly spaced longitudinally extending passage bores 44 in the head end of the valve member and into an annular radially opening distribution channel groove 45 spaced from the head end of the valve bore. In communication with the distribution groove 45 only during maximum spring biased position of the valve plunger 38 is a passage duct 47 (Figs. 3 and 4) in the face plate 12 which communicates with a delivery groove 48 provided in the internal periphery of the bore of the plate 12 and closed by the bushing ring 15 so as to provide a duct by which the pressure fluid is conducted around to the opposite side of the bore to a delivery passage duct bore 49 communicating through a port 50 (Figs. 1 and 2) with the sub-chamber portion of the modulator chamber 17 at the biased or primed end of the modulator. Thereby, during the initial operation of the pump and while pressure is developing the modulator member 18 is subject directly to a head of fluid under pressure to maintain the modulator in its maximum eccentric position with respect to the rotor 20 in opposition to pump torque tending to shift the modulator.

At the same time the opposite or housing abutting end of the modulator is relieved of pressure so as to afford a positive pressure differential between the primed and opposite end of the modulator. For this purpose a port 51 (Figs. 1 and 3) leads from the abutment end portion of the modulator chamber 17 which is in communication with the port 51 at both sides of the abutment end 31 of the modulator through a by-pass groove 52, and communicates with a passage 53 leading to the valve bore 39. The location of the passage 53 is such that it communicates with an annular peripheral communication groove 54 in the valve member 38 and from which lead a plurality of axially extending ports or bores 55 to the rear end of the valve member into the spring chamber by which communication is effected with the low pressure port 33 of the pump.

When the pump pressure attains a predetermined mean p. s. i. the valve biasing spring 40 is overcome to the extent that the communication grooves 45 and 54 in the valve plunger are shifted out of registration with the passages 4 and 3 responsive to movement of the valve member longitudinally rearwardly under the influence of the pressure fluid acting against its head end. This substantially locks the fluid within the prime end of the modulator chamber 17 and holds the modulator against displacement toward concentricity as long as the pump pressure remains at the predetermined mean.

Should the pump pressure exceed the predetermined mean automatic adjustment of the modulator occurs to move it from the position of maximum eccentricity relative to the rotor 20 toward a less eccentric position, and this is accomplished by further rearward shifting of the valve member 38 by action of the high pressure of the pump against the head end of the valve member. Thereupon, the high pressure distribution groove 45 of the valve member communicates with a passage 57 leading to a high pressure delivery port 58 (Figs. 1 and 3) by

which high pressure fluid is delivered to the abutment end portion of the modulator chamber 17. At the same time the communication groove 54 of the valve member communicates with a pressure bleed passage bore or duct 59 (Figs. 2 and 3) which leads to the communication passage groove 48 and thereby bleeds the prime end portion of the modulator passage 17 to the low pressure side of the pump so that the modulator is shifted to a position of reduced eccentricity relative to the pump rotor 20 proportionate to the tendency toward excessive pressure built up by operation of the pump and thus the mean output pressure of the pump is restored. Upon such restoration of mean output pressure the valve member 38 again shifts to the neutral position wherein all of the passages are blocked from communication and the modulator is maintained in the pressure locked condition while the output pressure remains at the mean constant.

According to the present invention marked improvement in stability of operation of the pump is attained by providing constant bleed of the prime end of the modulator chamber with the high pressure side of the pump and constant bleed of the opposite end of the modulator chamber to the low pressure side of the pump. For this purpose a grooved or bored duct 60 through the modulator ring 18 effects communication with the high pressure side of the pump within the pump chamber 19 adjacent to the high pressure port 34 and the sub-chamber at the prime end of the modulator. A groove or bore 61 in the modulator ring 18 communicates with the low pressure side of the pump adjacent the low pressure port 33. Best results have been attained by differential in size in the bleed passages 60 and 61 wherein the high pressure bleed 60 is of larger cross sectional flow area than the low pressure bleed 61. For example, when the high pressure bleed 60 is of approximately $\frac{1}{16}$ to $\frac{3}{64}$ inch in diameter, the low pressure or suction bleed may be $\frac{1}{32}$ inch in diameter.

Through the arrangement of a high pressure bleed to the spring or prime end of the modulator ring or block and a low pressure or suction bleed to the opposite end of the modulator, there is always a hydraulic force tending to move the modulator toward full eccentricity. In the initial operation of the pump this supplements the function of the high and low pressure communication passages through the control valve assembly 37. Then when the valve assembly functions to shift the modulator toward the concentric position the pressure differential established by the high and low pressure bleeds 60 and 61 operates to increase the bias on the valve with the result that the valve will ride in such a position that the openings created by the valve slots or grooves 45 and 54 and the communicating passages will be greater than in the absence of such an increase in the bias. The greater the size of these openings under normal operation, the less will be the rate of change of fluid flow through the openings with respect to the movement of the valve. This has an important beneficial effect on the stability of the system. However, since under normal operating conditions the fluid flow through the control valve is always in the same direction, except in the unusual cases of very rapid change of pumping volume requirements, flow reversals with their tendency to excite instability are eliminated. These have proved to be valuable practical features in this type of variable displacement pump.

The pump is also equipped for delivering hydraulic fluid such as oil pumped by the rotor 20 to lubrication and other points in the apparatus with which the pump is used. For this purpose, a port 62 (Figures 1 and 3) opens from the ported face of the face plate 12 adjacent to but spaced from the discharge end of the high pressure port 34 and in a position to be normally closed off by the modulator member 18 disposed in blocking relation thereto when the modulator member is in its maximum eccentric position. Upon development of such pump pressure in the pump as to effect partial movement

5

of the modulator 18 toward concentric position, the port 62 is exposed to the pump pressure. As a result, oil under pressure is delivered into a circular bore 63 which is intersected by the port 62.

Within the bore 63, the oil enters an annular groove 64 in a plunger valve 65 which is normally biased toward the blind end of the bore 63 by means of a coiled compression spring 67. A vented closure plate 68 provides an outer end abutment for the spring 67 and is retained in place in the mouth of the bore 63 by a snap ring 69.

From the annular groove or channel 64, the oil enters by way of a series of radial ports 70 in the head portion of the valve 65 into a blind end chamber bore 71 in the head of the valve opening from the head and communicating with a delivery passage 72 leading from the blind end of the bore.

As the pressure increases in and on the head portion of the valve member 65 beyond a predetermined biasing value or load of the spring 67, the valve member 65 shifts in opposition to the spring 67 and restricts or blocks the port 62, thus reducing and automatically maintaining a reduced pressure of the oil fed to the delivery duct 72. In this way the pressure of the oil used for lubrication or for keeping a torque convertor or fluid flywheel full is maintained at a predetermined value less than the mean output pressure of the pump.

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 a variable displacement pump including a casing defining a modulator chamber, a modulator member movable to and fro within said modulator chamber and having a pump chamber therein, a pump rotor operable in said pump chamber to create pump pressure in an eccentric position of the pump chamber relative to the rotor, said casing having inlet suction and outlet pressure ports leading to generally diametrically opposite portions of said pump chamber, means normally biasing the modulator into said position of eccentricity of said pump chamber relative to the pump rotor, said means including controlled passages for selectively subjecting generally diametrically opposite portions of the modulator within said modulator chamber outside of said pump chamber to pressure created by the pump, and means for continuously bleeding the modulator chamber at one of said portions of the modulator to the high pressure side of the pump and for continuously bleeding the modulator chamber at the opposite portion of the modulator to the suction side of the pump, whereby to provide during operation a continuous stabilizing hydraulic force tending to move the modulator toward said eccentric position.

2. In combination in a variable displacement pump assembly, a casing, said casing having a modulator chamber therein, a modulator in said chamber movable between generally diametrically opposite operative positions in said modulator chamber and dividing the modulator chamber into separate chamber portions, the modulator having a pump chamber therein, said casing having inlet and outlet passageways communicating operatively with said pump chamber, a rotor pumpingly operable in said pump chamber, fluid passages leading from the high pressure side of the pump to said opposite modulator chamber portions to subject the respective portions of the modulator exposed within said chamber portions to high pressure fluid, control valve mechanism for controlling flow of high pressure fluid through said passages to said chamber portions, and stabilizing bleeds continuously open in the operation of the pump between one of said chamber portions and the high pressure side of the pump and between the other of said chamber portions and the low pressure side of the pump, whereby to establish a pressure bias tending to effect movement of the modulator toward said other of said chamber portions.

3. In combination in a variable displacement pump as-

6

sembly, a casing, said casing having a modulator chamber therein, a modulator in said chamber movable between generally diametrically opposite operative positions in said modulator chamber and dividing the modulator chamber into separate chamber portions, the modulator having a pump chamber therein, said casing having inlet and outlet passageways communicating operatively with said pump chamber, a rotor pumpingly operable in said pump chamber, fluid passages leading from the high pressure side of the pump to said opposite modulator chamber portions to subject the respective portions of the modulator exposed within said chamber portions to high pressure fluid, control valve mechanism for controlling flow of high pressure fluid through said passages to said chamber portions, and stabilizing bleeds continuously open in the operation of the pump between one of said chamber portions and the high pressure side of the pump and between the other of said chamber portions and the low pressure side of the pump, whereby to establish a pressure bias tending to effect movement of the modulator toward said other of said chamber portions, said bleeds comprising respective passages through the modulator.

4. In combination in a variable displacement pump, means defining a casing, said casing having a modulator chamber therein, a modulator in said chamber, the modulator being proportioned to divide the modulator chamber into separated sub-chambers on generally diametrically opposite sides of the modulator, the modulator being mounted in the modulator chamber for movement from one sub-chamber to the opposite sub-chamber of said modulator chamber, a pump chamber in said modulator, a pump rotor operable in said pump chamber, said casing having a suction port and a separate high pressure port communicating with said pump chamber, a system of passages connecting said high pressure port with said sub-chambers, a control valve for said passages operative for selectively subjecting the modulator directly within said modulator sub-chambers to biasing influence of pump created pressure, and means for stabilizing operation of said modulator including a continuously open passage through the modulator from adjacent the high pressure port to one of said modulator sub-chambers and a continuously open passage through the modulator from the vicinity of the low pressure port communicating with the other one of said modulator sub-chambers.

5. In combination in a variable displacement pump, means defining a casing, said casing having a modulator chamber therein, a modulator in said chamber, the modulator being proportioned to divide the modulator chamber into separated sub-chambers on generally diametrically opposite sides of the modulator, the modulator being mounted in the modulator chamber for movement from one sub-chamber to the opposite sub-chamber of said modulator chamber, a pump chamber in said modulator, a pump rotor operable in said pump chamber, said casing having a suction port and a separate high pressure port communicating with said pump chamber, a system of passages connecting said high pressure port with said chambers, a control valve for said passages operative for selectively subjecting the modulator directly within said modulator sub-chambers to biasing influence of pump created pressure, and means for stabilizing operation of said modulator including a continuously open low pressure bleed passage through the modulator from adjacent the low pressure port to one of said modulator sub-chambers and a continuously open pressure bleed passage through the modulator from the vicinity of the high pressure port communicating with the other one of said modulator sub-chambers, said low pressure bleed passage being of smaller cross sectional flow area than the high pressure bleed passage.

6. In a variable displacement pump assembly, a housing structure providing an enclosure, a modulator member movable to and fro within said enclosure and having a pump chamber therein, a pump rotor operable in said

pump chamber to create pump pressure in an eccentric position of the pump chamber relative to the rotor, respective inlet and outlet fluid passage means leading to respectively opposite portions of said pump chamber for fluid circulation therebetween by operation of said pump rotor in said eccentric position of the pump chamber, means in said housing structure cooperating with respectively generally diametrically opposite sides of the modulator and at such opposite sides defining respective pressure chambers, said last mentioned means including controlled passages for selectively subjecting said pressure chambers to pressure created by the pump, and continuously open bleeder means for bleeding the pressure chamber at one side of the modulator to the high pressure side of the pump and for bleeding the pressure chamber at the opposite side of the modulator to the suction side of the pump for providing during operation of the pump

a continuous stabilizing hydraulic force tending to move the modulator toward said eccentric position.

7. A variable displacement pump assembly as defined in claim 6, wherein the bleeder means comprise, respectively, separate passages in the modulator member.

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