Aug. 10, 1954 G. H. HUFFERD **2,685,842**

VARIABLE DISPLACEMENT PUMP AND VOLUME CONTROL THEREFOR

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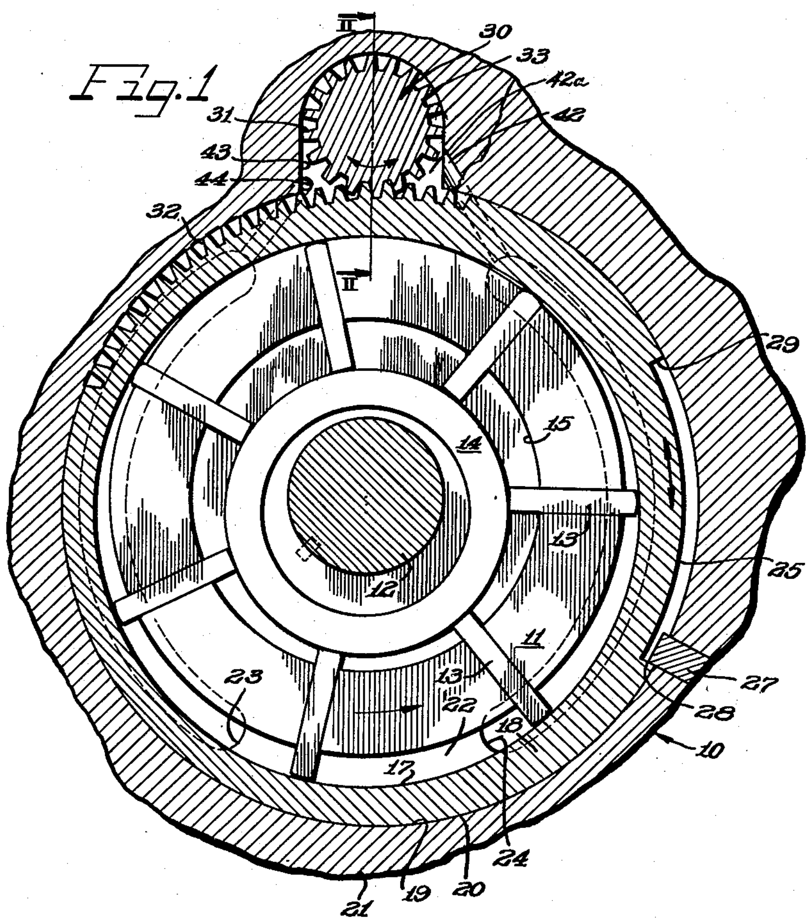
Fig. 1



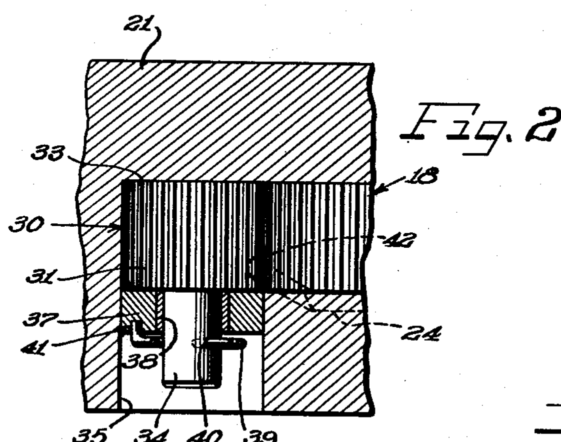


Fig. 2

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Fig. 3

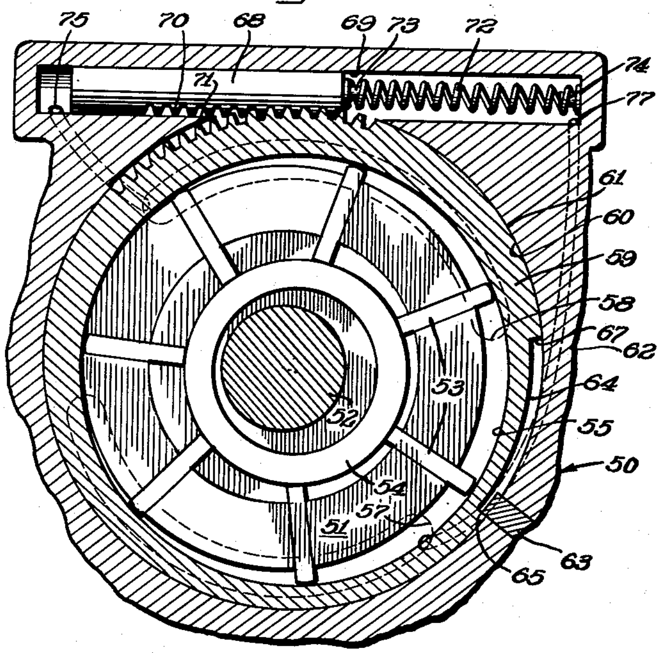
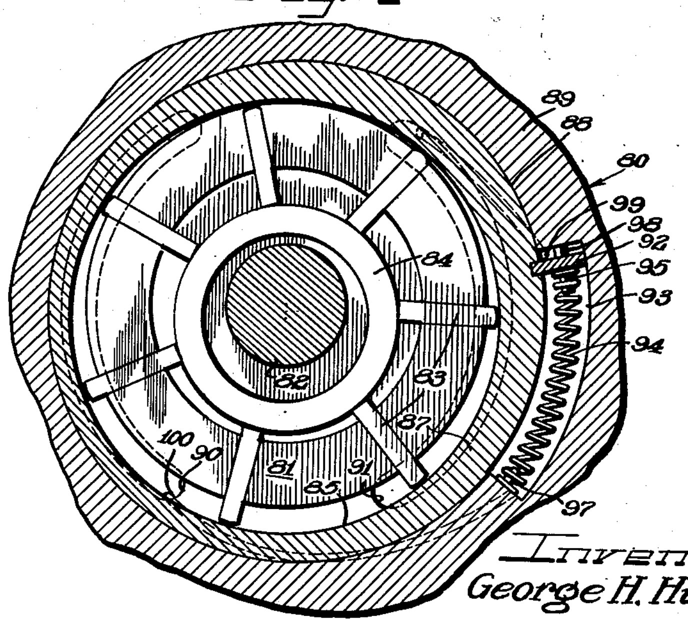


Fig. 4



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VARIABLE DISPLACEMENT PUMP AND VOLUME CONTROL THEREFOR

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5 Claims. (Cl. 103—120)

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This invention relates to improvements in reciprocal vane rotary pumps and more particularly concerns novel volume control for pumps of this type.

An important object of the present invention is to control the displacement of a variable displacement rotary pump by effecting movement of a displacement modulator automatically responsive to variations in pressure created by the pump itself.

Another object of the invention is to provide for the automatic rotary adjustment of a modulator ring of a variable displacement pump to maintain a substantially constant mean pressure at the output or high pressure side of the pump.

A further object of the invention is to provide improved control means for automatically shifting the modulator of a reciprocal vane type of variable displacement rotary pump directly responsive to the pressure of the high pressure side of the pump in operation and working against a mechanical pressure determining medium.

Still another object of the invention is to provide an improved constant pressure variable displacement pump which is self-controlling as to displacement so as to be capable of substantially constant pressure output in spite of many operating variables arising in the course of operation.

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 drawings in which:

Figure 1 is a fragmentary sectional detail view through a variable displacement pump embodying the principles of the invention;

Figure 2 is a fragmentary sectional detail view taken substantially on the line II—II of Figure 1;

Figure 3 is a fragmentary sectional elevational detail view of a modified form of the pump and control means therefor;

Figure 4 is a sectional elevational detail view of a further modified variable displacement pump and control means.

A pump 10 (Figs. 1 and 2) embodying one form of the control according to the present invention comprises a rotor 11 mounted concentrically on a drive shaft 12 and radially slotted to accommodate a series of radially reciprocable impeller vanes 13. The rotor 11 and the vanes 13 are of well known type wherein the inner ends of the vanes ride against respective guide rings 14 within circular respective clearance pockets or cavities 15 in the opposite sides of the rotor 11, the ring and cavity at only one side of the rotor being shown in Figure 1.

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In the operation of the pump the guide rings 14 maintain the outer ends of the vanes 13 in a common circle concentric with a circular pump chamber bearing face 17 eccentric to the axis of the rotor 11 and provided by a modulator member 18 operatively encircling the rotor. In the present instance the modulator 18 comprises a generally ring-shaped member encompassed by a circular bearing surface 19 with which a complementary circular external peripheral bearing surface 20 of the modulator and eccentric to the internal pump chamber surface 17 and is in slidable bearing relation. The circular bearing surface 20 may be formed in a casing or housing 21. By reason of the eccentricity of the cooperating bearing surfaces 19 and 20 to the pump chamber surface 17, rotary movement of the modulator 18 will cause eccentric adjustment of a pump chamber space 22 intervening between the eccentric chamber bearing surface 17 and the opposing periphery of the rotor 11. This alters the pumping displacement relationship of the pump chamber area 22 with respect to a generally kidney-shaped inlet port 23 and a similarly shaped outlet or delivery port 24. In the condition disclosed in Figure 1, the position of the modulator ring 18 is the predetermined maximum displacement relationship to the high pressure or discharge port 24. By shifting the modulator ring 18 clockwise as viewed in Figure 1 the pumping displacement will, of course, be diminished until a minimum displacement condition is obtained.

In order to control maximum rotary displacement adjustment movement of the modulator ring 18, the bearing surface 20 of the ring is preferably formed with an arcuate control slot or recess 25 into which projects a stop member or vane 27 from the opposing wall or face 19 of the casing 21. The length of the control recess determines the limits of rotary adjustment movement of the modulator ring, the stop vane 27 engaging a stop shoulder 28 at one end of the recess 25 to determine the condition of maximum displacement and being engageable with a stop shoulder 29 at the opposite end of the control recess to determine the condition of minimum displacement.

According to the present invention, the modulator member 18 is automatically controlled during operation of the pump to assume that particular displacement position relative to the rotor 11 at any given time which will maintain a substantially mean output pressure in the outlet port 24 at the high pressure side of the pump. To this end, means are provided comprising a servo-control member 30 which is responsive to pump-created pressure to actuate the displacement control member or modulator 18. In the form shown in Figures 1 and 2, the control member 30 comprises a relatively small spur motor gear having teeth 31 arranged to mesh with complementary gear teeth 32 formed as an arcuate rack in the outer periphery of the modulator ring 18 as best seen in Figure 1. The control gear 30 is preferably disposed substantially centered between the ends of the inlet and outlet ports 23 and 24 and is housed within a chamber 33, the walls of which closely surround the control gear in relatively close slidable bearing relation throughout the major extent of the gear periphery and at one side of the gear. The axis of the gear chamber 33 is so disposed that the portion of the chamber adjoining the modulator bearing wall 19 opens toward the periphery of the modulator sufficiently to assure efficient meshing of the gear teeth 31 with the modulator teeth 32.

Extending axially from one side of the control motor gear 31 is a stem 34 projecting into an access opening 35 in the casing 21 and through a narrow closure plug disk 37 providing a substantially fluid tight retaining wall for the edges and side of the control gear. Desirably a bushing bearing 38 is provided for the stub shaft or stem 34.

Means are provided for normally biasing the gear 30 rotatably to maintain the modulator ring 18 normally in its position of maximum displacement. Herein such means comprises a spiral torsion spring 39 encircling the portion of the stub shaft 34 projecting out from the closure disk wall 37. The inner extremity of the torsion spring 39 is engaged within an appropriate radial aperture 40 in the shaft 34 while the opposite extremity of the spring engages within an appropriate aperture 41 in the outer face of the closure disk 37. The weight, tension and loading of the spring 39 are predetermined to maintain the control gear 30, through the medium of the stub shaft 34, under predetermined torsional load and bias normally tending to drive the control gear 30 clockwise as viewed in Figure 1 to maintain a corresponding counter-clockwise bias on the modulator ring 18 toward maximum pump displacement as limited by the stop vane 27 engaging the stop shoulder 28.

The calculated torsional bias of the spring 39 substantially equals the predetermined mean pressure value for which the pump is to be rated, and means are provided for subjecting the control gear 30 as a fluid motor to the influence of the pressure side of the pump so that when the predetermined mean pressure is exceeded the control gear will operate in opposition to the torsion spring bias to adjust the position of the modulator 18 and reduce the pump displacement and thereby the output pressure of the pump and substantially re-establish the mean ouput pressure. To this end, a pressure duct 42 leads from the high pressure side of the pump at the outlet port 24 to a pressure cavity or enlargement 42*a* in the gear chamber and exposes to pump pressure the rack teeth 32 and the gear teeth 33 in the zone where they diverge due to curvature of the members and acting upon the gear and rack teeth dynamically in opposition to the spring bias of the control gear. As and to the extent that the pump pressure thus overcomes the torsional bias of the spring 39 and turns the motor gear 30, the modulator ring 18 and the pump displacement are diminished until pressure balance is attained and the pump output is again at its mean value.

A fluid bleed-off cavity or enlargement 43 of the gear chamber at the opposite side from the cavity 42*a* has a fluid return suction duct 44 leading therefrom to the low pressure inlet port 23 so that as fluid passes over into the cavity 43, it will be displaced to the low pressure side of the pump until the pressure in the outlet port 24 drops to a value below the spring bias pressure and reversal of the control gear and modulator occurs to increase pump displacement. Thus, it will be apparent that the servo-control gear 30 will be efficiently sensitive and responsive to fluid pressure imposed thereon peripherally through the high pressure duct 42 in opposition to the bias spring 39 and within the limits determined by the rotary adjustment stop 27 cooperating between the stop shoulders 28 and 29 in defining the range of adjustment oscillation of the rotary modulator 18.

In the modification of Figure 3, a reciprocal vane rotary pump 50 of substantially the same construction as the pump 10 is provided with a different form of servo-control means operative, however, similarly to the servo-control means for the pump 10 to adjust the displacement relationship of a modulator member to the rotor of the pump automatically in response to pump created pressures substantially in excess of the mean pump output pressure for which the pump is rated. The pump 50 comprises a rotor 51 mounted concentrically on a drive shaft 52 and is equipped with radially reciprocal pump vanes 53, the inner ends of which are in engagement with control rings 54 while the outer ends are in slidable bearing engagement with a circular pump chamber bearing wall 55 eccentrically related to the periphery of the rotor 51 and affording a pump chamber displacement area adequate for the purpose of the pump. An inlet port 57 and an outlet port 58 communicate with the pump chamber space. The pump chamber is provided by a modulator ring 59 which is encompassed by a circular bearing surface 60, and in slidable bearing relation to which is a circular outer peripheral bearing surface 61 on the ring and eccentrically related to the pump bearing chamber surface 55. The bearing surface 60 may be formed in a suitable casing or housing 62.

Pump displacement is modified by rotary movement of the modulator ring 59 within limits defined by a stop vane 63 projecting from the bearing wall 60 into an arcuate slot or recess provided in the outer periphery of the modulator ring and defined at its opposite ends by respective stop shoulders 65 and 67. Thus, when the modulator ring is moved to its extreme counter-clockwise rotary position as determined by the stop vane 63 engaging the stop shoulder 65, the pump is in its maximum displacement condition. When the modulator 59 is rotated clockwise to the limit defined by engagement of the stop shoulder 67 with the stop vane 63, the pump is in its minimum displacement condition.

Adjustment of the modulator ring 59 to maintain pump displacement automatically in accord with a predetermined rated mean output pressure of the pump while the pump is in operation comprises a fluid-driven servo-control motor including a plunger or piston 68 which is slidably reciprocable in a cylinder bore 69 in the housing or casing 62 and disposed substantially tangential to the modulator chamber as defined by the bearing wall 60. Appropriate end portions of the cylinder bore 69 extend beyond the point of tangential intersection so that a set of rack teeth 70 on the piston 68 will mesh and coact with a series of complementary gear teeth 71 on the periphery of the modulator ring by reciprocal movements of the piston.

Means are provided for normally biasing the piston 68 to drive the modulator 59 counter-clockwise as viewed in Figure 3 into its position of maximum pump displacement as defined by the stop vane 63 engaging the stop shoulder 65, such means therein comprising a coiled helical compression spring 72. One end of the spring 72 engages about a guide boss or stud 73 coaxial with the right end of the piston 68 as viewed in Figure 3 while the opposite end of the spring engages about a stationary stud or boss 74 projecting inwardly from the end wall of the cylinder chamber 69. The weight, compression characteristics and loading of the spring 72 are such that a biasing force is afforded of a magnitude equal approximately to a predetermined mean fluid output pressure of the pump as developed in the output port 58 and transmitted by way of a duct 75 to act upon the end of the piston 68 opposite the spring 72. The spring housing portion of the cylinder chamber 69 is relieved through a duct 77 communicating with the inlet port 57 of the pump. Thus, the spring 72 urges the piston 68 toward the left as viewed in Figure 3 to maintain the modulator 59 in its maximum counter-clockwise position of rotation as defined by the stop vane 63 and wherein the pump is in its condition of maximum displacement.

When during operation of the pump, pressure developed therein exceeds the predetermined mean output pressure for which the pump is rated, the excess pressure is reflected through ducts 75 on the free end of the piston 68 and the piston is moved in opposition to the bias of the spring 72 and the modulator ring 59 is rotated clockwise to the extent which will afford a pressure balance wherein the pump displacement is reduced sufficiently so that the predetermined mean pressure pump output is substantially resumed and maintained. Since the servo-control piston 68 is afforded a substantial range of reciprocal movement consistent with the full range of oscillation permitted the modulator ring 59, it will be observed that the mean output pressure of the pump is maintained substantially constant over a large range of possible tendencies toward deviation from such mean output pressure.

In Figure 4 is shown a pump 80 which is substantially the same in its operating details as the pumps 10 and 50 but has a modified servo-control engagement. In the pump 80 a rotor 81 is mounted concentric with a drive shaft 82 and has a series of radial vanes 83 with the inner ends thereof in engagement with control rings 84 while the outer ends of the vanes have slidable bearing, pumping impeller engagement with an inner circular pump chamber bearing surface 85 disposed eccentrically to the rotor 81 on an encircling modulator ring 87 and which is in turn rotatably slidably supported eccentrically by a bearing surface 88 afforded by a housing or casing 89. An inlet port 90 and an outlet port 91 communicate with the eccentric pump chamber afforded between the rotor and modulator ring. Pump displacement is controlled by rotary movement of the modulator ring 87 so that a maximum displacement with respect to the outlet port 91 is attained in substantially the counter-clockwise relative relationship of the modulator ring 87 as shown in Figure 4, while minimum displacement is in effect when the modulator ring is turned clockwise as viewed in Figure 4. In the present instance the limits upon rotary or oscillating movements of the modulator 87 are defined by a radial vane member 92 which projects from the periphery of the modulator ring into an arcuate clearance recess or chamber 93 in the surrounding housing 89.

In the present instance, the oscillation range-controlling vane 92 serves also as a part of a fluid motor servo-control system for automatically adjusting the modulator ring 87 for displacement control in response to pump created pressures deviating from a mean pump pressure output. To this end, the vane 92 makes relatively close bearing, substantially fluid sealing slidable contact with the walls defining the clearance grooves 93. Means for biasing the vane 92 into the maximum displacement position of the modulator 87 comprises a coiled, helical compression spring 94 which is preferably curved on an arc generally parallel to the adjacent periphery of the modulator 87 and has one end engaged about a pin 95 projecting from the surface of the vane 92 while the opposite end of the spring is engaged about a stationary pin or boss 97 which projects from the engaged end wall defining the clearance groove 93. The opposite end wall of the clearance groove 93 or the vane 92 has a protruding stud or boss 98 which affords a stop for the vane 92 under the impulse of the biasing spring 94 and affords a definite clearance into which the mouth of a pressure duct 99 opens to conduct pressure fluid from the outlet port 91 into the space at the side of the vane 92 opposite the biasing spring.

The biasing spring 94 is of a weight, resiliency characteristic and compression loading to exert a biasing pressure against the vane 92 which will normally maintain the modulator 87 in its position of maximum pump displacement with a force equal to a predetermined mean output pressure for the pump. Hence, until the mean pressure is exceeded at the high pressure side of the pump as reflected by way of the communication duct 99 on the fluid pressure side of the vane 92, the biasing spring 94 will maintain the modulator ring in its maximum displacement position. However, upon the output pressure being exceeded, the fluid pressure acts upon the control vane 92 in opposition to the biasing spring 94 to shift the vane and thereby the modulator ring 87 to decrease the pump displacement and thus effect a balanced condition wherein the mean output pressure is substantially resumed. For pressure relief of the spring housing chamber portion of the clearance groove 93, a fluid duct 100 communicates with the spring-engaged end of the chamber and the inlet or low pressure port 90. It will be observed that in the minimum displacement position of the modulator 87 where it has been rotated by the pump pressure in opposition to the biasing spring 94 in a clockwise direction as viewed in Figure 4, the pin or boss members 95 and 97 will serve as limiting stops.

It will be observed that in all forms of the invention the predetermined pressure value is a function of a biasing means operating normally to maintain a modulator member in a maximum displacement position with respect to the pump rotor. In each instance a servo-control or fluid operated motor acting in opposition to the biasing means automatically shifts the modulator to decrease the pump displacement and thus maintain a predetermined mean pressure at the high pressure or output side of the pump by controlling the volume of fluid displaced by the pump.

An important aspect of the present pump construction resides in that the displacement control mechanism has a great mechanical advantage over the forces to be controlled and thus hunting may be eliminated and the imbalance forces within the pump itself may be ignored. The only force within the pump that might tend to combat stable control is the frictional drag of the vanes against the inner or pump chamber surface of the control ring or modulator. This is a readily calculatable value and can be used as a datum line above which the control spring becomes effective in the calculations entering into the engineering of a pump of the present type embodying the invention for any particular size or predetermined operating factors.

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

I claim as my invention:

1. In combination in a variable displacement pump of the character described, a fluid displacing rotor, a modulator providing a pump chamber normally eccentrically disposed relative to the rotor and within which the rotor is operative to displace fluid through the pump chamber, said modulator being mounted for adjustment relative to the rotor to vary the relative fluid displacement eccentricity of the pump chamber and the rotor in operation, a portion of the modulator having a rack, a spur gear hydraulic motor having teeth meshing with said rack, a torsion spring acting on said gear to bias the same normally in one direction for maintaining the modulator in one position, and hydraulic means cooperatively related to the spur gear for driving the spur gear in the opposite direction from said spring bias when the modulator is to be shifted from said one position.

2. In combination in a variable displacement pump of the character described, a fluid displacement rotor, a modulator providing a pump chamber normally eccentrically disposed relative to the rotor and within which the rotor is operative to displace fluid through the pump chamber, means providing a suction passage communicating with the low pressure side of the pump chamber, means providing a high pressure pump output passage communicating with the high presure side of the pump chamber, said modulator being mounted for adjustment relative to the rotor to vary the relative fluid displacement eccentricity of the pump chamber and the rotor in operation, means enclosing the modulator and providing a motor chamber opening toward the modulator, a motor member in said motor chamber coacting with the portion of the modulator exposed to said motor chamber for shifting the modulator to vary said fluid displacement eccentricity, said motor chamber being substantially isolated from both of said passages but having a fluid passage duct communicating with the suction passage and operative at one side of the motor member and a second fluid duct communicating with the high pressure passage and active on the opposite side of the motor member, said motor member being responsive to the low pressure on said one side and the high pressure on the other side for movement in said motor chamber and thereby acting to shift the modulator toward decrease in displacement eccentricity of the pump chamber relative to the rotor, and a spring normally acting on said one side of the motor member and in opposition to the high pressure communicated to the motor chamber through said high pressure duct to resist movement of the motor member under the influence of high pressure created by the rotor in operation.

3. A variable displacement pump as defined in claim 2, wherein the motor member comprises a spur gear rotatably mounted in said motor chamber and coacting with the modulator by meshing with rack teeth thereon, and said spring comprises a torsion spring attached at one end in stationary relation to said enclosing means and at the other end attached under torsional bias to the spur gear motor member, with the full torsional bias of the spring operatively acting on the low pressure (said one) side of the spur gear motor member.

4. A variable displacement pump as defined in claim 2, wherein the motor member comprises a reciprocable plunger slidably mounted in the motor chamber which for this purpose comprises an elongated cylinder bore in the enclosing means, the coaction of the plunger member with the modulator being through the medium of respective meshing rack teeth on the plunger and the modulator periphery, and the spring comprises a coiled compression spring disposed under biasing compression by thrusting at one end against an end wall defining the low pressure side of the pump chamber and the opposite end thrusting against the end of the plunger motor member comprising the low pressure (said one) side of the motor member.

5. A variable displacement pump as defined in claim 2, wherein the motor member comprises a vane mounted in coacting relation with the periphery of the modulator and projecting into the motor chamber to divide the motor chamber into said high pressure and low pressure sides, and the spring comprises a coiled compression spring thrusting at one end against a stationary wall defining the low pressure side of the motor chamber opposing said vane motor member while the opposite end of the spring thrusts biasingly against the low pressure (said one) side of the vane motor member.

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