Aug. 7, 1945. F. W. TAYLOR 2,381,162

HYDRAULIC SYSTEM FOR STABILIZERS

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Fig. 1.

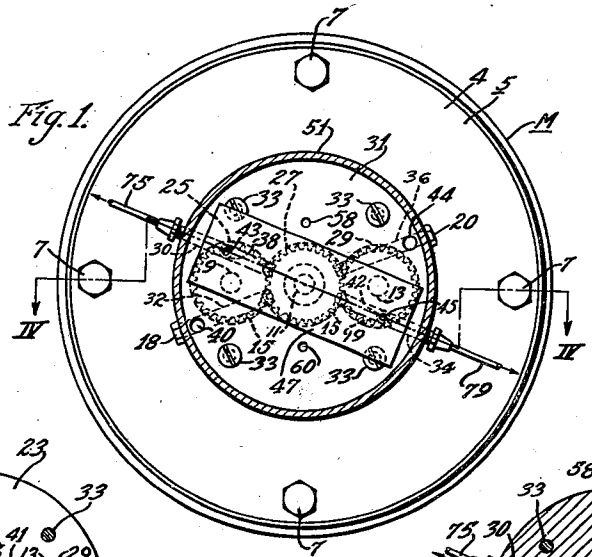


Fig. 2.

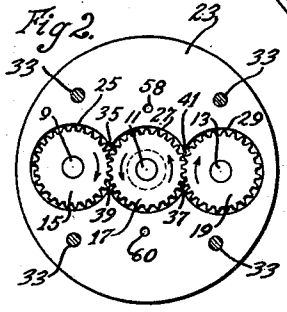


Fig. 3.

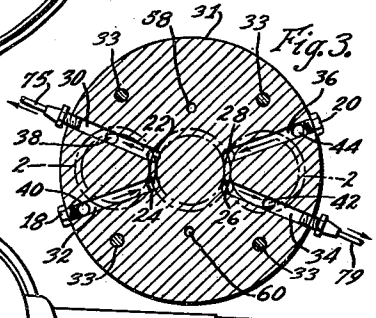


Fig. 4.

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HYDRAULIC SYSTEM FOR STABILIZERS

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7 Claims. (Cl. 103—41)

My invention relates to hydraulic systems for stabilizers and the like and it has for an object to provide improved apparatus of this character.

A more specific object of the invention is to provide, for a relatively movable element and a support coupled by reciprocating hydraulic means subject to the opposed action of two liquid pressures to effect relative adjustment of the element and support, two sources for supplying liquid under pressure to the hydraulic means together with valves for the respective sources and operative to secure such relations of supplied pressures as to actuate the hydraulic means for stabilizing the element in relation to the support.

A further object of the invention is to provide, for an element pivotally mounted on a support and coupled to the latter by reciprocating hydraulic means subject to the opposed action of two liquid pressures to effect relative adjustment of the element and support, two sources supplying liquid under pressure to the hydraulic means together with valves for the respective sources and controlled electrically to secure such relations of supplied pressures as to actuate the hydraulic means for effecting positional adjustment of the element and support.

A further object is to provide means for furnishing two supplies of motive liquid under suitable relative pressures to secure actuation of a servo-motor and wherein the pressures are simultaneously changed by valves for the respective supplies and which valves are under control of a control member movable in opposite directions from a mean position.

Still another object of the invention is to provide two simultaneously-operating and positive-displacement pumps whose outlet or supply passages have liquid bypassed therefrom by means of passages provided with valves operated by an actuator moved for this purpose in response to position of a control member, the arrangement being such that, with the control member in mean position, the valves are positioned for the maintenance of a predetermined relation of pressures in the supply passages and, with departure of the control member from mean position in either direction, the valves are moved to increase one pressure and decrease the other according to the direction of departure.

Further objects and advantages will become more apparent from a study of the following specification when considered in conjunction with the accompanying drawing, in which:

Figure 1 is a section on line I—I of Fig. 4 showing a pump in accordance with my invention in its assembled form;

Fig. 2 is a section on line II—II of Fig. 4.

Fig. 3 is a section on line III—III of Fig. 4, showing oil passages in the pump head or cover plate; and

Fig. 4 is a schematic view of one form of system to which my invention is adaptable; the section of the pump being substantially on the line IV—IV of Fig. 1.

Referring to the drawing, a description of the pump will now be given.

A motor M has turned in its end bell an annular groove 1 into which is fitted a ring member 3 within the opposite end of which is seated against a shoulder the flange-like portion 4 of a circular plate 5, the entire assembly being secured to the motor by means of bolts 7 extending through holes in said flange, the threaded ends of said bolts engaging tapped holes in the motor housing end bell. Circular plate 5 forms the base of the pump having therein bearings for receiving the stub shafts 9, 11 and 13 of meshing gears 15, 17 and 19. The center gear 17 of this gear train is driven by the motor M; its axis being aligned with the motor shaft 21 to receive and have keyed within a bore in its stub shaft 11 the end of the motor shaft 21 to effect direct drive by the motor. A circular plate 23, of a thickness to provide running clearance for the gears, has openings 25, 27 and 29 for the gears extending therethrough. The pump housing is completed by a circular plate or cover plate 31 positioned adjacent to the plate 23 and having radial oil passages 30, 32, 34 and 36 formed therein, the passages 32 and 36 serving as pump inlet passages and the passages 30 and 32 as pump outlet or supply passages. The contacting surfaces of the plates comprising this laminated construction are ground to provide an oil-tight seal when brought into contact. The assembly is bolted together by a plurality of bolts 33 extending through plates 23 and 31 and engaging threaded holes drilled and tapped into, but not through, plate 5. The radial oil passages, see Fig. 3, are preferably drilled so that their radial axes lie in substantially a single plane, and these passages are connected to the gear chamber by ports 22, 24, 26 and 28 drilled vertically so as to provide pump inlets 24 and 28 and pump outlets 22 and 26.

The pump housing also forms one wall of the oil reservoir 51, its cover plate 31 having openings 40 and 44 connecting the reservoir to the inlet passages 32 and 36 so that the latter function

as pump inlet or suction passages communicating with the reservoir.

Assuming for the moment, rotation of the gears as indicated by the arrows in Fig. 2, it will be seen that in the spaces 35 and 37 where the gear teeth come into mesh, that a squeezing-out action on the oil in those spaces will occur, and conversely, in the spaces 39 and 41 where the teeth of the gears are disengaged a pulling or sucking-in action on the oil in that space will occur. The pressure or outlet oil ports of the pump will, therefore, be located in the spaces 35 and 37 while the inlet ports will be located in the spaces 39 and 41. By using the three gears in train, as shown, two simultaneously-operative, positive-displacement and equal-capacity pumps result and which are formed as a single compact unit to provide two separate sources of liquid pressure.

The sump, or oil reservoir side of the cover plate 31, is connected to the radial oil passages 30, 32, 34 and 36 by holes drilled vertically into this face of plate 31 into the oil passages. The holes 38 and 42 tapped into the pressure or supply passages are drilled to align with the oil holes 43 and 45 in the base 47 of the magnetic valve assembly 49 mounted on the reservoir side of plate 31, to form by-pass passages for the pump outlet or discharge passages for by-passing liquid from the latter to the reservoir. The holes 40 and 44 (see Fig. 3) leading into the inlet passages 32 and 36 are drilled near the edge of plate 31 to avoid interference with the magnetic valve assembly, and the ends of the radial passages 32 and 36 are closed with plugs 18 and 20. The magnetic valve assembly is sealed within the reservoir chamber 51. A sealing plate 53 is bolted to the motor side of plate 5 and is of sufficient diameter that a gasket 55 shall include within its seal the three bearings of the gear train 15, 17 and 19. A small chamber 56 is provided within the oil seal of plate 53 for the purpose of permitting circulation of the oil through the stub shaft bearings, said chamber being connected to the sump or oil reservoir through holes 58 and 60 drilled completely through the laminated pump housing assembly. A packing gland 57 about the motor shaft 21 completes the seal of the chamber. Such small leakage as may occur through packing gland 55 is drained from the motor pump assembly through a hole 59 in the ring 3. The above construction permits circulation of the lubricating fluid through the stub shaft bearings, thereby preventing their binding.

A type of system to which the pump is particularly adapted is schematically shown in Fig. 4. A current furnished by a battery 61 or other source of energy is normally equally divided between the right and left-hand portion of a resistor 62, since it forms parallel paths extending, respectively, through valve actuating coils 63 and 65. Two valves 67 and 69, cooperating with seats provided in the by-pass passages and facing in the directions of flow through the latter, are interconnected by a common valve actuating element 71 pivoted at 73 and which abuts the valves to limit opening thereof by liquid pressure forces acting thereon, both valves being normally open because of normal equal energization of coils 63 and 65 which actuate the element 71 controlling the poppet or seated type valves 67 and 69. The pump outlet or supply passages 30 and 34 are connected by the supply pipes 75 and 79 to the lower and upper portions, respectively, of the cylinder 77. Since, as has been stated, the valves are normally open to a predetermined relative extent, as determined by the normal position of the actuator or rocker 71, the fluid pressures on opposite sides of the piston 81 are in such relation as to keep the piston in a fixed position. As a consequence thereof, there will be no torques exerted by the piston about the trunnion axis 83 of the element being stabilized and consequently such element will be maintained in its angular position with respect to the trunnion axis. As long as the forces exerted by liquid pressures acting on opposite faces of the piston 81 are in equilibrium, the piston remains in fixed position; however, with reciprocal movement of the valves in relation to their seats, one valve moving in a closing direction and the other in an opening direction, flows through the by-pass passages are correspondingly varied and the differential pressure condition thereby created causes piston movement. A leakage line 85 is connected to the oil reservoir chamber 51 and leads directly through the packing seal through which the piston rod reciprocates, so that as excessive pressure is developed in the piston chamber, oil will leak into the line 85 instead of being forced through the packing seal. A controlling device 87 comprising a plurality of flexible contact members tapped on resistor 62 is operated by the actuating (or pilot) element 89, and is herein used to unbalance the currents in valve actuating coils 63 and 65. As shown, the leaf spring contacts 91 are arranged as right-hand and left-hand groups with the actuating element 89 disposed therebetween. For the function of this controlling device with reference to the velocity of displacement and displacement of a gun, or element to be stabilized, reference may be had to a copending application of C. R. Hanna, Serial No. 366,877, filed Nov. 23, 1940, entitled "Gun stabilizers." For the purpose of my description, however, the contact actuating element 89 may be assumed to be controlled manually since any means for unbalancing the valve currents will be satisfactory. The improvement in this instance over said patent application is confined to the pump system. Movement of the actuating element 89 to the left will progressively close the contacts 91 of the left-hand group while opening those of the right-hand group, decreasing the resistance through the left-hand portions of resistor 61 while increasing the resistance through the right-hand portion. It will be seen that more current will flow through valve actuating coil 65 due to the decrease of resistance in series therewith, which will effect clockwise movement of valve actuating element 71 to move the valve 67 in a closing direction while further opening the valve 69. As a consequence of this, the larger pressure developed in the line 75 will be supplied to the lower portion of the chamber of the cylinder 77, to push the piston 81 upwardly, which, by virtue of its connection with the element or body whose position is controlled, will rotate said element or body clockwise to decrease its elevation angle. Movement of the piston in either direction due to pressure differences may occur as liquid at the lower pressure side is expelled by backflow through the associated supply passage and discharged through its by-pass. Also, as hereinbefore pointed out, the fluid pressures developed by the pumps exert forces on the valves 67 and 69 for the reason that each valve defines, with respect to its seat, an orifice and presents an area subject to the upstream pressure of the latter. As each orifice is restricted, the upstream pressure is increased to increase the fluid pressure

force acting on the valve. Movement of the actuating member 71 in consequence of a change in the relation of magnetic forces due to a disturbance is accompanied by an opposed change in the relation of the fluid pressure forces with the result that the actuating member has an equilibrium-seeking tendency. Whenever the controlling member 89 ceases to change its position to change the current values of the supplies for the windings 63 and 65, the magnetic forces of the latter cease to change and equilibrium of the actuating member 71 is attained when the clockwise moments due to magnetic and fluid pressure forces exerted on the latter are equal to the counterclockwise moments. Movement of the actuating element 89 to the right obviously has the opposite effect on the contacts and the hydraulic means controlled thereby.

The stabilizer is equipped with an additional feature of control preventing substantial deviation or departure of the element or gun from wanted position when subject to the effect of unusually large unbalancing torques, such as those due to gun recoil and which may be of a magnitude many times larger than those normally acting on the system. Since the relatively short periods of recoil, usually of one-half second duration, render impractical the construction of a system sufficiently large to cope with these unbalances, an additional coil 93 has been added to the pole piece controlling valve 67, and is connected in series with the battery 61. A recoil switch 95 normally biased closed by a spring, is maintained open by the gun breech and closed during recoil when the gun breech recedes therefrom, energizing the valve coil 93 and firmly closing valve 67, diverting full pressure of the associated side of the pump to the bottom chamber of cylinder 77, thus firmly coupling the gun to its mount and supporting it during the recoil period. A ball or check valve 97 is installed in the pump output which leads to the bottom portion of the cylinder chamber to prevent the back pressure exerted by the piston during recoil unbalance from entering the pump when it is in excess of the peak delivery of the pump. The hydraulic pressures in the cylinder 77 are controlled by their respective valve currents. As the stiffness regulator resistor 99 is adjusted to increase the valve currents and magnetic flux densities, negative stiffness is also increased. Regarding the definition of "stiffness," a body is said to have positive stiffness if its resistance increases upon compression, such as is inherent in a spring. An electromagnet has negative stiffness, since, as the armature is attracted toward the core, a smaller and smaller force is required. If such negative stiffness increases beyond the positive stiffness, arising from the hydraulic pressure on the valves, unstable operation occurs. The range of instability may be varied by changing the valve clearances, air gaps, or other constants and may be kept low by keeping the total valve currents at a minimum value. Relief valves 101 and 103 are installed in pressure outlets connected to the sump for the purpose of preventing air from being pumped or drawn into the hydraulic system, in the event the gun should be moved in elevation manually. The mechanical advantage in this case would be large and the pumping action of the piston could possibly draw air through any of the oil line connections.

The pump design as shown, is simple in construction and has few wearing parts. It forms, in effect, two separate pumps, but has the advantage of being a compact unit requiring but one motor for its drive.

I am, of course, aware that others, particularly after having had the benefit of the teachings of my invention, may devise other devices embodying my invention, and, I, therefore, do not wish to be limited to the specific showings made in the drawing and the descriptive disclosure hereinbefore made, but wish to be limited only by the scope of the appended claims.

I claim as my invention:

1. In apparatus providing two simultaneously-effective supplies of motive liquid for a pressure-responsive device, first and second simultaneously-operating, positive-displacement gear pumps; a reservoir for liquid; passages for the supplies of liquid open to the outlets of the respective pumps; pump inlet passages communicating with the reservoir; bypass passages for conducting liquid from the respective supply passages to the reservoir and having valve seats facing in the direction of flow therethrough; a pair of valves movable toward and away from said seats to change the flows through the by-pass passages in order to change the supply passage pressures; mechanism for connecting said valves so that the force of liquid pressure applied to one valve is opposed by that applied to the other; said mechanism including a rocker, stems connected to the valves and abutting opposite ends of the rocker, and pivot means for the central portion of the rocker and reacting to oppose liquid pressure forces exerted thereon; a controlling member movable in opposite directions from a mid position; and means for applying oppositely-acting tilting forces to said connecting mechanism and responsive to departure of the controlling member from mid position in opposite directions to vary the tilting forces relatively to control the positions of the valves relative to their seats and consequently the relative liquid pressures in said supply passages so as to provide, with the controlling member in mid position, for a predetermined relation of pressures in the supply passages and to provide, with departure of the controlling member from mid position, for increase in one supply passage pressure and decrease in the other supply passage pressure according to the direction and extent of departure.

2. The combination as claimed in claim 1 wherein the pumps are of equal capacity and are comprised by two gears individual to the pumps and meshing with an intermediate gear common to the pumps.

3. The combination as claimed in claim 1 wherein at least one of the supply passages is provided with a check valve opening away from the associated pump outlet.

4. In apparatus providing two simultaneously-effective supplies of motive liquid for a pressure-responsive device, first and second simultaneously-operating, positive-displacement and equal-capacity gear pumps; passages for the supplies of liquid open to the outlets of the respective pumps; a reservoir for liquid; pump inlet passages communicating with the reservoir; by-pass passages for conducting liquid from the respective supply passages to the reservoir and having valve seats facing in the direction of flow therethrough; a pair of valves movable toward and away from said seats to change the flows through the by-pass passages in order to change the supply passage pressures; mechanism for connecting said valves so that the force of liquid pressure applied to one valve is opposed by that applied to

the other; said connecting mechanism including a rocker, stems connected to the valves and abutting opposite ends of the rocker, and pivot means for the central portion of the rocker and reacting to oppose liquid pressure forces exerted thereon; a controlling member movable in opposite directions from a mid position; a pair of electro-magnets for applying oppositely-acting tilting forces to the connecting mechanism; a pair of circuits for supplying electrical energy in parallel from a suitable source to the windings of the electro-magnets; and variable resistances in the circuits and cooperating with the controlling member to vary relatively the oppositely-acting tilting forces applied to the connecting mechanism to control the positions of the valves relative to their seats and consequently the relative liquid pressures in said supply passages so as to provide, with the controlling member in mid position, for a predetermined relation of pressures in the supply passages and to provide, with departure of the controlling member from mid position, for increase in one supply passage pressure and decrease in the other according to the direction and extent of departure.

5. In apparatus providing two simultaneously-effective supplies of motive liquid for a pressure-responsive device, first and second pumps comprising a pair of gears meshing with an intermediate gear and a housing for the gears; a reservoir for liquid; said housing forming one of the walls of the reservoir and including a cover plate; a pair of pump inlet passages formed in the cover plate and communicating with the reservoir; a pair of passages for the liquid supplies having portions formed in the cover plate and open to the outlets of the pumps; by-pass passages formed in the cover plate for conducting liquid from the supply passages to the reservoir and having valve seats facing in the directions of flow therethrough; a pair of valves movable toward and away from said seats to vary the flows through the by-pass passages in order to vary the supply passage pressures; an actuating member abutting the valves, cooperating with the latter so that the force of liquid pressure applied to one valve is opposed by that applied to the other, and operative to move the valves in a reciprocal manner; a controlling member movable in opposite direction from a mid position; and means for applying oppositely-acting forces to the actuating member and responsive to departure of the controlling member from mid position in opposite directions to control the positions of the valves relative to their seats and consequently the relative liquid pressures in said supply passages so as to provide, with the controlling member in mid position, for a predetermined relation of pressures in the supply passages and to provide, with departure of the controlling member from mid position, for increase in one supply passage pressure and decrease in the other according to the direction and extent of departure.

6. The combination as claimed in claim 5 wherein the cover plate is provided with ports connecting the supply passages and the reservoir and check valves to close the ports in response to pressures in the supply passages and developed by the pumps.

7. In apparatus providing two simultaneously-effective supplies of motive liquid for a pressure-responsive device, first and second pumps comprising a pair of gears meshing with an intermediate gear and a housing for the gears; a reservoir for liquid; said housing forming one of the walls of the reservoir and including a base plate and a cover plate; journals connected to the gears and fitting bearings extending through the base plate; a driving shaft connected to one of the journals; a plate having sealed attachment with respect to the outer face of the base plate and having an opening through which the driving shaft extends; a packing gland having sealing relation with respect to the driving shaft and carried by the sealing plate in order that the latter may form, with respect to the base plate, a sealed chamber open to the outer ends of said bearings; at least one passage formed in said housing for connecting said sealed chamber to the reservoir; a pair of pump inlet passages formed in said cover plate and communicating with the reservoir; a pair of passages for the supplies of liquid including portions formed in said cover plate and open to the outlets of the respective pumps; by-pass passages formed in said cover plate for conducting liquid from the supply passages to the reservoir and having valve seats facing in the directions of flow therethrough; a pair of valves movable toward and away from said seats to vary the flows through the by-pass passages in order to vary the supply passage pressures; an actuating member abutting the valves, cooperating with the latter so that the force of liquid pressure applied to one valve is opposed by that applied to the other, and operative to move the valves in a reciprocal manner with respect to their seats; a controlling member movable in opposite directions from a mid position; and means for applying oppositely-acting forces to the actuating member and responsive to departure of the controlling member from mid position in opposite directions to control the positions of the valves relative to their seats and consequently the relative liquid pressures in said supply passages so as to provide, with the controlling member in mid position, for a predetermined relation of pressures in the supply passages and to provide, with departure of the controlling member from mid position, for increase in one supply passage pressure and decrease in the other according to the direction and extent of departure.

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