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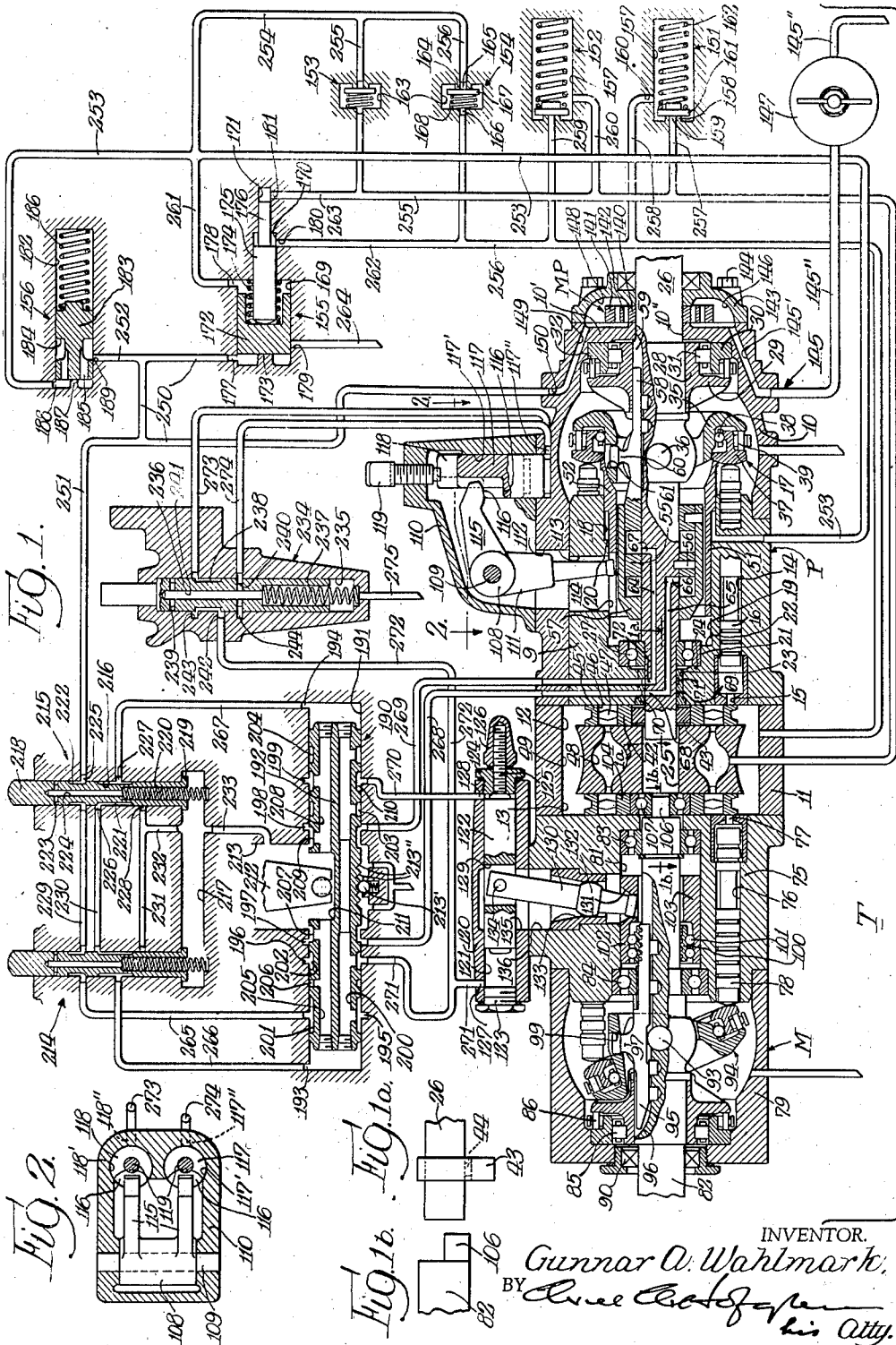
G. A. WAHLMARK

2,383,092

HYDRAULIC CIRCUIT

Filed Sept. 15, 1941

2 Sheets-Sheet 1



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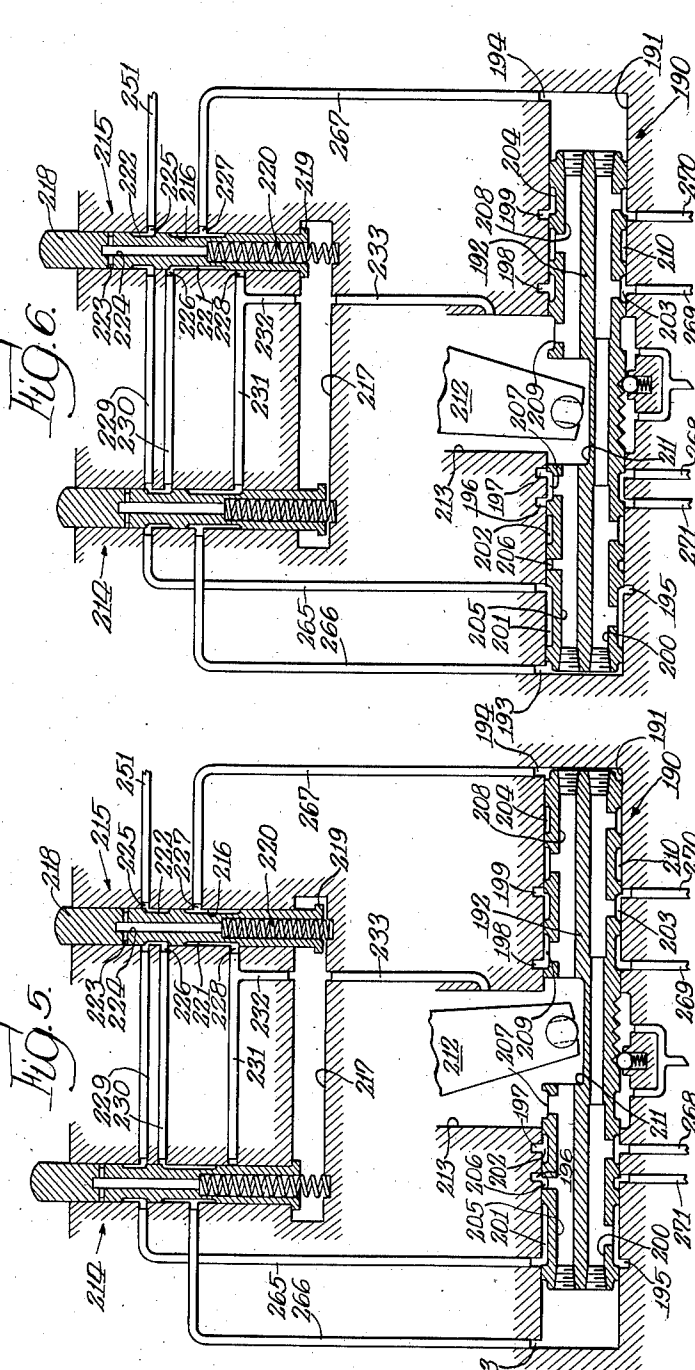
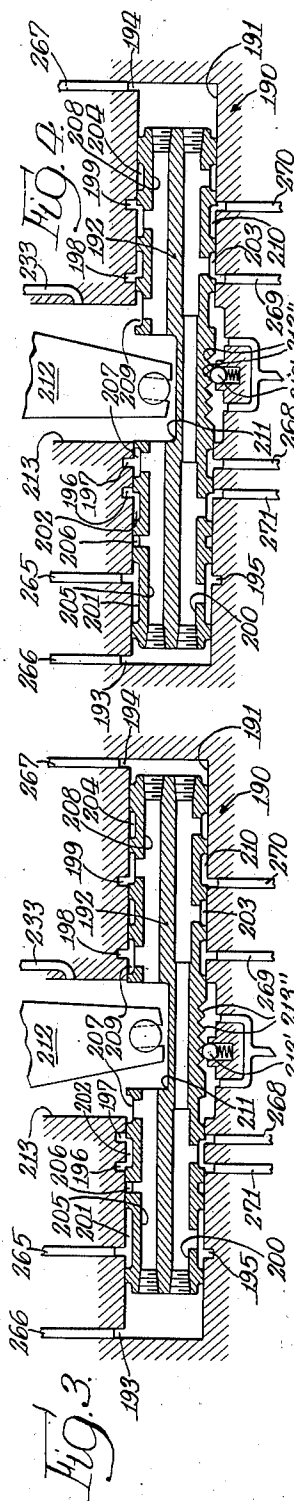
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2,383,092

HYDRAULIC CIRCUIT

Filed Sept. 15, 1941

2 Sheets-Sheet 2



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2,383,092

HYDRAULIC CIRCUIT

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Application September 15, 1941, Serial No. 410,860

18 Claims. (Cl. 103—5)

The invention relates to a hydraulic circuit, including a hydraulic transmission composed of a pump and a motor, and relates more particularly to such a circuit especially adapted for use with machine tools.

One object of the invention is to provide a hydraulic circuit of new and improved construction resulting in enhanced operation.

Another object is to provide in a circuit having a variable displacement pump and a motor means operable automatically with an increase in the working pressure of the pump to increase slightly the pump displacement to compensate for increased leakage at such increased working pressures.

Another object is to provide in a circuit having a variable displacement pump with a control member governing the displacement of the pump means operable to maintain a constant pressure on the control member regardless of variation in the working pressure of the pump.

Another object is to provide in a circuit, having a main pump and a motor with a closed circuit, a make-up and control fluid pump, and means responsive to the working pressure of the main pump operable with an increase in pressure to increase the pressure of the make-up pump, permitting low make-up pump pressure at idling and normal working pressures of the main pump.

Another object is to provide in a circuit having a variable and reversible displacement pump with a control member governing the volume of displacement and hydraulic means operable independently to govern the direction of displacement and conjointly with the control member to govern the volume of displacement, means for supplying control fluid, and means responsive to the working pressure of the pump to increase the pressure of the control fluid supplied to the hydraulic means with an increase of the working pressure.

Still another object is to provide in a circuit, including a pump and motor, hydraulically actuated means for governing the direction of operation of the motor and pilot valve means of new and improved construction controlling the supply of operating fluid to the hydraulically actuated direction governing means.

Still another object of the invention is to provide a direction governing valve means including a hydraulically shiftable valve member having a neutral position and a position on either side of neutral, and plunger valves normally maintaining no pressure on the shiftable valve member.

Other objects and advantages will become ap-

parent from the following detailed description taken in connection with the accompanying drawings, in which:

Fig. 1 is a diagrammatic view of a circuit embodying the features of my invention.

Fig. 1a is an enlarged detail view taken along the line 1a—1a of Fig. 1.

Fig. 1b is an enlarged detail view taken along the line 1b—1b of Fig. 1.

Fig. 2 is a fragmentary view taken along the line 2—2 of Fig. 1.

Fig. 3 is an enlarged view of the reversing valve means only of the directional control valve means showing the same in one feed position.

Fig. 4 is a similar view of the reversing valve means but showing the same in the opposite feed position.

Fig. 5 is an enlarged view of the directional control valve means showing the same in one traverse position.

Fig. 6 is a view similar to Fig. 5 but showing the valve means in the opposite traverse position.

While the invention is susceptible of various modifications and alternative constructions, it is here shown in the drawings and will hereinafter be described in a preferred embodiment. However, it is not intended that the invention is to be limited thereby to the specific embodiment disclosed. On the contrary, it is intended to cover all modifications and alternative constructions falling within the spirit and scope of the invention as defined in the appended claims.

The circuit comprises generally a hydraulic motor, generally designated M, a main pump, generally designated P, for supplying operating fluid to the motor, and an auxiliary pump, generally designated MP, for supplying make-up and control fluid. The pump and the motor are connected in a closed hydraulic circuit which is provided with suitable relief valves to prevent excessive high pressures and with check valves to prevent the working pressure from backing up against the make-up pump. The main circuit additionally includes a valve means for controlling the pressure of the fluid discharged by the make-up pump, valve means for providing a supply of make-up and control fluid under constant pressure, valve means for controlling the direction of operation of the motor, and valve means for determining the rate of operation of the motor, particularly the feed rate of operation. Preferably the pump and motor are arranged in an end to end relationship and may be enclosed in a single housing to form a unitary transmission such as that disclosed in my co-

pending application Serial No. 414,587, filed October 11, 1941. Among other things, the housing provides a reservoir or tank T for the fluid employed in the circuit.

The pump P is of the wobbler type and basically is identical in construction with the pump disclosed in my copending application Serial No. 410,861, filed of even date herewith. The pump P comprises a cylinder block 9 having one end, herein its outer or right hand end, non-rotatably received within a casing member 10. At the end of the cylinder block opposite the casing member 10, in fact interposed between the pump and the motor, is a common valve block 11. The faces of the valve block 11 are formed with circular recesses 12 and 13, of which the recess 12 with the end of the cylinder block 9 forms a valve chamber housing valve means, more particularly described hereinafter.

The cylinder block 9 is formed with a plurality of parallel, longitudinally extending and annularly arranged cylinders 14 opening at their left ends, as viewed in Fig. 1, to the valve chamber 12 through an annular series of ports 15, and at the other ends opening without restriction to the interior of the casing member 10. Reciprocable in each cylinder 14 is a piston 16 adapted in all positions to extend partially from the cylinder block for engagement by an actuating means, generally designated 17. Extending axially of the cylinder block is a stepped bore having a first portion 18 opening through the right hand end of the cylinder block, as viewed in Fig. 1, a second portion 19 of slightly smaller diameter so as to form an annular shoulder 20, a third portion 21 of still smaller diameter so as to form an annular shoulder 22, and a fourth and final portion 23 of still smaller diameter to form a shoulder 24. Extending longitudinally of the pump with its inner end projecting through the valve chamber 12 and into a recess 25 in the block 11, and with its outer end projecting outwardly of the casing member 10 for connection with a motor, is a shaft 26. Near its inner end the shaft is journaled in a roller bearing 27 seated in the portion 21 of the stepped bore, while near its outer end the shaft is surrounded by a sleeve 28 formed with a radially projecting flange 29. The casing member 10 is provided with an inwardly extending annular flange 10' providing a circular opening 10'' through which the shaft 26 projects. Mounted in the casing member 10 adjacent the flange 10' is an annular ring 30, generally L-shaped in cross section, and between the ring and the sleeve 28 there is interposed a roller bearing 31, while between the ring and the flange 29 there is interposed a roller bearing 32, respectively supporting the shaft radially and against end thrust.

The actuating means 17 here takes the form of a wobbler composed of an inner annular member 35, pivotally mounted on the shaft 26 by means of a pin 36, and an outer annular ring member 37. This ring member 37 is rotatable relative to the inner member 35, and to that end is generally T-shaped in cross section, and interposed between the members 35 and 37 is a ball bearing 38, to take the radial thrust, and a roller bearing 39, to take the end thrust. The member 37 is, of course, disposed to engage the projecting ends of the pistons 16, and to that end the ends of the pistons, as well as the surface of the member 37 contacted thereby, are rounded. Herein the curvature given to the ends of the pistons and to the surface of the member 37 is such that the moment arms of that half of the wobbler on one side

of the pin 36 (in Fig. 1, upper half) will have such proportion with respect to the moment arms of that half of the wobbler on the other side of the pin 36 (in Fig. 1, lower) as to tend to cause the reaction of the pistons on the wobbler to restore the same to neutral or no-stroke position.

In order to control the flow of fluid into or out of the cylinders 14, there is interposed in the chamber 12 a wheel-like or spoked valve 42, such as more particularly disclosed and claimed in my Patent No. 2,190,812, dated February 20, 1940. This valve is mounted eccentrically with respect to the shaft 26 and to that end such eccentric mounting is here obtained by the employment of an eccentric cam 43 non-rotatably secured on the end of the shaft 26 by means such as a pin 44. The outer rim or periphery 45 of the valve 42 serves, due to the eccentric movement of the valve, to connect the ports 15 alternately to the outer circumferential portion of the chamber 12, or to an annular passage 46 formed by the spokes 47 of the valve. This annular passage in the valve is always in communication with an annular passage 48 formed in the block 11 which opens to the chamber 13 in a manner similar to its opening to the chamber 12. The outer portions of the chambers 12 and 13 are interconnected by a passage 49 to complete a hydraulic circuit between the pump and the motor.

Unique governing means of a character more particularly disclosed and claimed in my copending application Serial No. 410,861, filed of even date herewith, are herein provided for determining the position of the wobbler. Comprising this governing means is a cylindrical control member or cam 51 slidable longitudinally in the portion 19 of the stepped bore in the cylinder block 9, so as to be concentric of the shaft 26 and also concentric of the wobbler 17. At its right hand end, as viewed in Fig. 1, the control cam 51 is enlarged to form a piston 52 slidable in the portion 18 of the stepped bore. At its extreme right hand end the control cam 51 is provided with an end edge disposed in a plane at right angles to the shaft 26 and adapted to bear against the inner member 37 of the wobbler to determine the angular position of the wobbler. The piston portion 52 of the control cam 51, in cooperation with the shoulder 20, forms a hydraulic means which, as presently will become more apparent, is utilized to place the wobbler under a pre-load of a predetermined constant pressure. The angular position of the wobbler 17 is determined by longitudinal shift of the control cam 51. Shift to the right is, of course, limited and determined by contact of the cam with the wobbler 37 throughout its entire circumference, the wobbler in this position being disposed strictly at right angles to the shaft in an absolute zero or no-stroke position. Shift of the control cam to the left, as viewed in Fig. 1, is limited by abutment of the end of the cam with the shoulder 22. Intermediate positions of the cam are determined by means later described.

Shift of the wobbler from one side to the other of its neutral position to obtain reversal of operation of the pump, that is reversal in the direction of fluid discharge, is obtained by means operating independently of the control cam 51. Herein this means is hydraulic and comprises an annular piston 55 fixedly secured on the shaft 26 by means such as a pin 56. Cooperating with the piston is a cylinder 57 having a narrow extension 58 slidable in a groove 59 formed in the periphery of the shaft for that purpose. Extending radially from the extension 59 is an arm 60

received in a suitable socket 61 formed in the inner member 35 of the wobbler.

Passages for the supply of operating fluid to opposite ends of the cylinder 57 are formed in part in the shaft 26. Extending longitudinally of the shaft is a passage 65 connected by a radial passage 66 to the left hand end of the cylinder 57 at a point immediately adjacent the piston 55. A similar radial passage 67 opens to the right hand end of the cylinder 57 immediately adjacent the piston 55 and communicates at its inner end with a longitudinal passage 64. At its left hand end, the passage 65 is connected by a radial passage 68 to an annular groove 69 formed internally of a sleeve or bushing 70 in the reduced portion 23 of the stepped bore. Spaced from the groove 69 is a similar groove 71 connected by a radial passage 72 to the passage 64. The grooves 69 and 71 are supplied with control fluid, as hereinafter more particularly described.

The motor M is also of the wobbler type and is generally similar to the pump P. Like the pump, it is comprised in the main of a cylinder block 75 having formed therein a plurality of annularly arranged and longitudinally extending cylinders 76, each of which opens at its inner or right hand end, as viewed in Fig. 1, through a port 77 to the recess 13. Reciprocable in each of the cylinders is a piston 78, at all times projecting through the end of the cylinder opposite the port 77. The inner or right hand end wall of the cylinder block 75 cooperates with the recess 13 to form a valve chamber, while the outer or left hand end of the cylinder block is non-rotatably received within a casing member 79.

Formed in the cylinder block 75 is a longitudinally extending bore 81, and extending longitudinally of the motor centrally of the bore 81 is a shaft 82 projecting at its left end, as viewed in Fig. 1, outwardly of the casing member 79. The shaft 82 is journaled at its inner end and intermediate its ends in ball bearings 83 and 84, respectively. Near its outer end, it is journaled in a pair of roller bearings 85 and 86 the same as the pump shaft. Surrounding the shaft and closing the opening in the casing member 79, through which the end of the shaft projects, is a conventional seal 90.

Pivotaly mounted on the shaft 82 on a pin 93 is a wobbler, generally designated 94, identical with the wobbler 17 of the pump. The angular position of the wobbler with respect to the shaft 82, and hence the displacement of the motor, is governed by a bar 95 slidable longitudinally of the shaft in a groove 96. Intermediate its ends, the bar is provided with an arm 97 terminating in a rounded head received in a socket 99 approximately formed in the wobbler 94. At its inner end the bar 95 is engaged with the inner race 100 of ball bearings 101, the outer race of which is formed by an extension 102 of an annular member 103 slidable and rotatable relative to the shaft 82. The member 103 is shifted longitudinally of the shaft to vary the displacement only of the motor by means presently to be described.

The flow of fluid from the pump to the motor is controlled by a wheel-like valve 104 identical with the valve 42. This valve operates in the valve chamber 13 and is driven in timed relation with the reciprocation of the pistons by the shaft 82. As best seen in Fig. 1b, there projects eccentrically from the end of the shaft and into the chamber 13 a stud 106. This stud is received

in a ball bearing 107 interposed between the stud and the valve.

Individual means are provided for determining intermediate positions of the control cam 51 of the pump and for shifting the annular member 103 of the motor. Herein the means for shifting the control cam of the pump includes a crank 108 pivoted on a pin 109 journaled in an upstanding housing 110 secured to the casing member 10. The crank has an arm 111 projecting through registering apertures 112 and 113 formed in the casing member 10 and the cylinder block 9, respectively, into engagement with a slot 114 formed in the control cam 51. A forked arm 115 of the crank extends at right angles to the arm 111 to cooperate with a shoulder 116 formed on each of a pair of pistons 117 and 118 (see Figs. 1 and 2). The pistons 117 and 118 are reciprocable, respectively, in cylinders 117' and 118' formed in part in the housing 110 and in part in the casing member 10. Opening to the lower end of the cylinder 117' is a port 117'', and opening to the lower end of the cylinder 118' is a port 118''. Threaded through the housing 110 in position to be abutted by the pistons 117 and 118 are a pair of limit screws 119 adjustable to determine the extent of upward movement of the pistons 117 and 118 under the influence of control fluid supplied to the lower ends of the cylinders. As best seen in Fig. 1, the screws 119 determine the position of the shoulders 116 and thus the extent of rotation in a clockwise direction of the crank 108. Such limitation of the clockwise rotation of the crank 108 in turn limits the shift of the control cam 51 to the left, and thus determines the positions of the control cam intermediate the extreme positions previously mentioned. This means is employed, as will presently become more apparent, to determine the position of the control cam when it is desired to obtain a feed rate of operation of the motor M, and it is to that end that the various parts are positioned and proportioned.

The means for shifting the annular member 103 of the motor is hydraulic and comprises a cylinder 120 having a bore 121 extending longitudinally thereof, in which is reciprocable a double-ended piston 122. The cylinder is closed at its ends by caps 123 and 124 threaded thereto, with the cap 124 having threaded therein and adapted to extend therethrough an adjusting screw 125 protected by a screw cap 126. The cylinder has opening to one end thereof a port 127, and opening to the other end thereof a port 128. Intermediate its ends the piston 122 is provided with a recess 129 into which projects one end of a lever 130, the other end of which projects into a socket 131 formed in the annular member 103. The lever is pivoted intermediate its ends and for that purpose is formed with a ball-like enlargement 132 received in a socket 133 formed in a bushing received in the cylinder block 75. The lever 130 is secured to the piston 122 by means of a pin 134, and, of course, the cylinder 120 and the casing member 79 are provided with registering apertures 135 and 136, respectively, to permit movement of the lever 130 under the influence of the piston 122. As fluid is supplied to one end or the other of the cylinder 120, the piston is shifted either to the position shown, or to the left, into abutment with the cap 123. When in abutment with the cap 123, however, the wobbler has not been reversed but has merely been returned to an approximate perpendicular or no-stroke position. Control fluid for the various hydraulic devices

heretofore described and make-up fluid for the closed pump-motor circuit is supplied by the make-up pump MP previously mentioned. This make-up pump is of the rotary gear element type disclosed and claimed in my Patent No. 2,132,813, dated October 11, 1938, and comprises generally (see Fig. 1) an inner gear element 140 fixed on the shaft 26 to be driven thereby, an outer gear element 141, and a crescent shaped dividing member 142. The elements operate in a chamber formed by the outer end face of the casing member 10 and an end closure 143 secured by bolts 144 to the casing member 10. Fluid is drawn into the pump through an intake passage, generally designated 145, and composed of a bore 145' in the casing member 10 and a conduit 145''. The passage communicates at one end with the tank T and terminates at the other end in an enlarged recess 146 forming the intake port for the make-up pump. A strainer 147 preferably is interposed in the intake passage. A similar enlarged recess 148 forms the discharge port for the make-up pump, and leading from this recess is a make-up and control fluid supply passage 149 terminating in a threaded port 150.

Incorporated in the circuit to perform various functions, primarily the governing of the fluid supplied by the make-up pump, are a plurality of valve means including a pair of high pressure relief valve means, generally designated 151 and 152, a pair of check valves, generally designated 153 and 154, a control fluid pressure governing valve means, generally designated 155, and a pressure reducing valve means, generally designated 156. These valve means are all described, particularly as to physical structure, in my copending application Serial No. 410,861, filed of even date herewith. Suffice it to say, therefore, that each of the high pressure valve means comprises a bore 157 opening to the end of which, through an annular seat 158, is a port 159, and opening to the side of which is a port 160. Cooperating with the seat 158 is a disk valve 161 urged to seated position by a strong compression spring 162. Each of the check valve means comprises a bore 163 opening to the end of which, through an annular valve seat 164, is a port 165, and opening to the other end of which is a port 166. A disk valve 167 is urged to seating position by a light compression spring 168.

The control pressure governing valve means 155 is formed with three bores 169, 170 and 171, successively decreasing in diameter. Reciprocable in the first bore is a piston valve 172 urged toward engagement with a boss 173 by a light compression spring 174. Reciprocable in the bore 170 is a plunger 175 having a reduced portion 176 reciprocable in the bore 171. The area of the end of the reduced portion 176 and of the annular shoulder formed on the plunger 175 surrounding the reduced portion 176 are equal. Opening to the annular chamber formed about the boss 173, so as to be constantly open, is a port 177, and opening to the opposite end of the bore 169, and also always open, is a port 178. Opening to the side of the bore 169 spaced inwardly somewhat from the end carrying the boss 173, so as to be controlled by the piston valve 172, is a port 179. This port, as clearly seen in Fig. 1, is closed when the piston valve 172 abuts the boss 173. Opening to the end of the bore 170 is a port 180, and opening to the end of the bore 171 is a port 181. The function of the valve means 155, and particularly the purpose of the equal areas on the plunger

175, will be described in greater particularity hereinafter.

The pressure reducing valve comprises a bore 182 in which is reciprocable a cylindrical valve 183. The valve is formed intermediate its ends with an annular groove 184, and extending longitudinally of the valve are a plurality of passages 185 opening at one end to the groove 184 and at the other end opening through the end of the valve. The valve is urged by a compression spring 186 to abut a boss 187. Opening to the annular chamber formed about the boss 187 is a port 188, and opening to the side of the bore 182 is a port 189 controlled by the valve 183. The port 189 is so located that it registers with the groove 184 when the valve abuts the boss 187, and is gradually closed as the valve is shifted away from the boss against the action of the spring 186. The valves just described can all conveniently be located directly in the transmission proper, usually the valve block 11, in much the same manner more fully disclosed in my copending application Serial No. 410,861, filed of even date herewith.

Forming a feature of this invention, and therefore not disclosed in the related cases, is a directional control valve means, generally designated 190. This means comprises a valve bore 191 in which is reciprocable a valve 192 of the cylinder type. Opening to one end of the bore is a port 193, and opening to the other end of the bore is a port 194, while intermediate those ports the bore is formed with five annular grooves 195, 196, 197, 198 and 199, suitably spaced to permit cooperation with the valve 192, as will later become more apparent. The valve 192 is formed with a passage 200 extending longitudinally thereof, but not opening through the ends thereof, and communicating with a wide annular recess 201 formed externally of the valve at one end thereof and with three narrower annular recesses 202, 203 and 204. Also formed in the valve, in one-half thereof, is a longitudinal passage 205 communicating with external annular recesses 206 and 207, while formed in the other half of the valve is a passage 208 communicating with annular recesses 209 and 210. These longitudinal passages, likewise, do not open through the ends of the valve, but do open to a recess 211 formed centrally of the valve. The recess 211 is provided to receive the end of an arm 212 of manually or dog operable means for shifting the valve which is not here disclosed, but which is disclosed in my application Serial No. 350,475, filed August 3, 1940. Incidentally the casing housing the valve means 190 is formed with a chamber 213 to accommodate the arm 212, which chamber is connected to the tank. In the position shown in Fig. 1, the valve 192 occupies a neutral position and may be shifted either to the right or to the left to occupy a feed or a traverse position on either side of neutral. Positions nearest neutral are feed positions, and positions on one side of neutral represent forward operation of the motor, while positions on the other side of neutral represent reverse operation of the motor. The valve is yieldably held in its positions by a conventional means, such as a spring pressed detent 213' engaging notches 213''.

The valve 192 is also intended to be shifted hydraulically from one extreme position through neutral to the other extreme position. Such shift is here under the control of a pair of plunger valve means, generally designated 214 and 215. These valve means are identical and each com-

prises a valve bore 216 opening at its inner end to a chamber or recess 217. Reciprocable in the bore is a valve 218 projecting through the outer end of the bore 216 so as to be capable of actuation by means such as a dog, and formed on its inner end with a flange 219 disposed in the chamber 217 and serving to limit the outward movement of the valve which is constantly being urged outwardly by a compression spring 220. The valve is provided with a wide annular recess 221 formed externally thereof and a narrow annular recess 222 disposed outwardly of the recess 221. Disposed beyond the recess 222 is a leakage fluid trapping groove 223 which communicates through radial ports with a longitudinal passage 224 extending through the inner end of the valve. The valve bore 216 is formed with an annular groove 225 and ports 226, 227 and 228. Each valve has two positions, namely, that shown in Fig. 1, and that shown in Fig. 5. In the position shown in Fig. 1, the recess 222 registers with groove 225, recess 221 registers with ports 226 and 227, and port 228 is closed. In the position shown in Fig. 5, recess 222 bridges groove 225 and port 226, while port 227 is now bridged with port 228 by the recess 221. The grooves 225 of the valve means are interconnected by a passage 229, the ports 226 are connected by a passage 230, and the ports 228 are connected by a passage 231, which is by a passage 232 connected to the chamber 217, which in turn is by a passage 233 connected to the chamber 213 and thus to the tank. The other connections between the valve means 214 and 215 and the valve means 190 will be described in connection with the description of the connection of these valve means in the general circuit.

Completing the various valve means incorporated in the circuit is a feed valve means, generally designated 234, which governs, as will presently become apparent, the supply of control fluid to the cylinders 117' and 118'. This valve means comprises a valve bore 235 in which is reciprocable a valve 236 projecting outwardly of the bore at one end for actuation by suitable means, such as a dog. The valve is urged outwardly of the bore by a compression spring 237 and is formed with a wide annular recess 238 and narrower annular recesses 239 and 240 on opposite sides of the recess 238. Both the recesses 239 and 240 are connected by radial ports with an axial bore 241 opening through one end of the valve to the bore 235. The valve bore 235 in turn is formed with a port 242 flanked on either side by a groove 243 and a groove 244. The valve has two positions, namely, that shown in Fig. 1, wherein the recess 238 bridges the groove 243 and the port 242 with the recess 240 of the valve registering with the groove 244, and a position shifted axially inwardly of that shown in Fig. 1, wherein the recess 238 bridges port 242 and groove 244, while recess 239 registers with grooves 243.

The manner in which the various valve means, as well as the hydraulic devices, are connected in circuit will now be described. Leading from the port 150 is a make-up and control fluid conduit 250. This supply conduit is connected direct to the port 177 of the pressure governing valve means 155 and, by a branch conduit 251, is connected to the port 225 of the directional control valve means to supply control fluid at the pressure maintained by the valve means 155. A branch conduit 252 is connected to the port 199 of the pressure reducing valve means 156. The valve means 156 operates in well known manner to reduce the pressure of the fluid in the conduit

250 to maintain a constant pressure in the annular chamber about the boss 187. By way of example, the pressure herein maintained is in the order of 100 pounds per square inch. This constant pressure furnishes the make-up fluid for the closed pump-motor circuit and also furnishes fluid at constant pressure for the control cam 51. To that end, a conduit 253 leads from the port 188 direct to the annular space formed between the shoulder 20 and the piston portion 52 of the control cam 51. Branching from the conduit 253 is a conduit 254 dividing into conduits 255, 256, respectively, leading to the passages 48 and 49 formed in the valve block 11, and having respectively interposed therein the check valves 153 and 154. These check valves are arranged in well known manner to permit flow from the conduit 254 to the passages 48 and 49, but preventing flow in the reverse direction. The high pressure relief valves 151 and 152 are connected to the conduits 255 and 256 to relieve fluid from the discharge or working side of the closed circuit and to return it to the return side should the working pressure become excessive. More particularly, a conduit 257 leads from the conduit 255 to the port 159 of the valve means 151, while the port 160 of this valve means is by a conduit 258 connected to the conduit 256. In like manner the port 159 of the valve means 152 is connected to the conduit 256 by a conduit 259, while the port 160 is connected to the conduit 255 by the conduit 260.

Aiding the spring 174 of the valve means 155 to maintain the supply conduit 250 at at least the pressure desired to be maintained by the pressure reducing valve means 156, a branch conduit 261 leads from the conduit 253 to the port 178 of the control fluid pressure governing valve means 155. In order to maintain pressures varying with the working pressures of the main pump regardless of the direction in which the main pump is discharging, the ports 180 and 181 are, respectively, connected by conduits 262 and 263 to the conduits 256 and 255, thus subjecting the equal areas formed on the plunger 175 to the working pressure of the main pump at all times. The excess fluid supplied by the make-up pump and discharged through the valve means 155 is returned to the tank or reservoir through a conduit 264 leading from the port 179.

Certain of the connections between the various ports or grooves of the directional control valve means have already been described. Complementing those described is a passage or a conduit 265 leading from the groove 225 of the valve means 214 to the groove 195 of the valve means 190 and leading from the ports 227 of the valve means 214 and 215 are conduits 266 and 267, respectively, connected to the ports 193 and 194. The grooves 197 and 198 are by conduits 268 and 269 connected, respectively, to the annular grooves 69 and 71 formed in the sleeve 23 surrounding the pump shaft 26 so as to supply control fluid to opposite sides of the cylinder 57. Groove 199 is by a conduit 270 connected to the port 128 of the motor displacement governing device, while groove 196 is by a conduit 271 connected to the port 127 of that device.

A conduit 272 branches from the conduit 271 to supply control fluid to the feed valve means 234 and to that end is connected to the port 242. The annular grooves 243 and 244 of this valve means are by conduits 273 and 274 connected, respectively, to the ports 118' and 117' of the feed control cylinders 116' and 117'. Fluid re-

turned from the cylinders 117' and 118' and leakage fluid are discharged to the tank through means including a conduit 275.

For a better understanding of the invention, the operation will now be described. Let it be assumed that the shaft 26 of the pump P is being driven and that the valve means are in the positions shown, more particularly, that the valve 192 is in its neutral position and that the valve 236 is in its outer position.

Under those circumstances, the make-up pump MP will be discharging make-up and control fluid to the conduit 250, which will then flow through the conduit 251, groove 225 of valve means 215, connecting passage 229, groove 225 of valve means 214, and conduit 265 to groove 195 of the valve means 190. Though control fluid thus is supplied to the longitudinal passage 200, neither end of the cylinder 57 is under pressure since the grooves 197 and 198 are now connected to the tank. With no pressure acting in either end of the cylinder 57, but with the reaction of the piston 16 of the main pump P on the wobbler 17 tending to restore the same to its no-stroke position, coupled with the action of the fluid on the control cam 51, the wobbler 17 will be returned to its absolute neutral or no-stroke position. With no fluid discharged by the main pump P, the pressure governing valve means 155 maintains only the minimum pressure for which it is adjusted, namely, approximately 110 pounds per square inch, which is sufficient to supply make-up and also to pre-load the wobbler through the hydraulic means formed in part by the control cam 51. Thus, though the pump is being driven, no fluid is being supplied to the motor M. It will be apparent that under these conditions the make-up pump need supply fluid only at the low pressure required for make-up and for placing the wobbler under a constant pre-load, which pressure, as previously stated, is in the order of 100 pounds per square inch.

If now the operator is ready to initiate operation of the motor, it is only necessary that the valve 192 be shifted. The initial shift will, of course, be through the manual means and may be either to one of the feed positions or to one of the traverse positions. Let it be assumed that it is desired to drive the motor at a feed rate and that the valve 192 has been shifted to the right as shown in Fig. 3. Under those circumstances control fluid will still be supplied through the conduit 265 to the longitudinal bore 200 of the valve. In this position of the valve, recess 202 opens to both grooves 196 and 197. Thus control fluid is supplied through the conduit 268 to the left hand end of the cylinder 57, thereby through the extension 58 urging the wobbler 17 away from its absolute zero displacement position perpendicular to the shaft 26. Fluid from the right hand end of the cylinder 57 is discharged through radial passage 67, passage 64, radial passage 72, groove 71, and conduit 269 to groove 198, recess 209, and longitudinal passage 208 to the tank. At the same time control fluid is supplied through the conduit 271 to the left hand end of the cylinder 120, the right hand end of the cylinder 120 being through conduit 270 connected to groove 199 which is now also open to tank through the recess 210 and longitudinal passage 208. The piston 122 in the cylinder 120 will thus be shifted to the right to the position shown in Fig. 1 and will, through the lever 130, shift the member 103 to the left, tilting the wobbler 94 to the maximum stroke

position which, of course, is the slow speed or feed rate position of the motor wobbler. With the supply of control fluid to the conduit 271, there is also a supply of control fluid through the conduit 272 to the port 242 of the feed valve means 234. In the position shown, this valve means 234 conducts the control fluid from port 242 to groove 243 and thence through conduit 273 to the cylinder 118', shifting the piston 118 upwardly until it abuts its adjustable limit screw 119, all as shown in Fig. 1. The piston 118 in turn determines the position of the crank 108 and as here adjusted permits only slight shift of the control member 51 to the left. The pump will thus have but a small displacement which, coupled with the large displacement of the motor, will result in operation of the motor at a slow feed rate.

It is believed clearly understood from the foregoing description that the cylinder 57 and the piston 55 are of such dimensions that the force generated by the action thereon of the control fluid at the pressure maintained by the valve means 155 is at all times sufficient to overcome the reaction of the pistons on the wobbler and the force of the control member 51, so that the wobbler is at all times held against the end edge of the control member 51.

In order that the pressure of the wobbler on the edge of the control member 51 may remain constant regardless of the variation of the working pressure in the pump, due to the variations in load on the motor, the valve means 155 is provided which acts in response to increases in the working pressure of the main pump P to raise the pressure of the control fluid and hence of the fluid acting in the cylinder 57. Excess control and make-up fluid is supplied by the make-up pump MP, and the excess fluid is returned to the tank or reservoir through the valve means 155 and particularly the conduit 264. In order that this control valve means may be responsive to the working pressure, the ends of the bores 170 and 171 are connected to the passages 48 and 49, as previously described, so that the pressure of the working fluid may be transmitted to the valve means 155 for either direction of operation of the pump. The areas acted upon by the fluid supplied through ports 180 and 181 are equal so that the same force for a given working pressure is exerted regardless of the direction of operation of the pump. This force will, of course, vary directly with the working pressure in the pump and thus will serve to maintain in the conduit 250 a varying pressure increasing with increases in the working pressure of the main pump. This variation in pressure is, of course, transmitted to the cylinder 57 and thus will counteract and offset the increased reaction of the pistons on the wobbler and will thus maintain the pressure of the wobbler on the control member 51 constant and uniform. While this variation in pressure in the cylinder 57 maintains constant the pressure of the wobbler on the control member 51, it nevertheless serves slightly to increase the displacement of the pump. This is accomplished by actual yielding of mechanical parts, the few thousandths of an inch necessary, as more fully explained in my copending application Serial No. 410,861, filed of even date herewith. Though the pressure of the control fluid thus varies in accordance with the working pressure of the pump, the make-up fluid supplied to the closed pump-motor circuit and the fluid for pre-loading the control member 51 is

maintained at a constant pressure. The fluid for both make-up and pre-loading is supplied through conduit 253, which is connected to the port 188 of the pressure reducing valve means 156 and thus is always supplied with a fluid under constant pressure.

A different feed rate of operation of the motor may be obtained with shift of the valve 236 inwardly to a position where recess 238 bridges grooves 242 and 244. Under those circumstances, control fluid is supplied through the conduit 274 to the end of the cylinder 117', causing the piston 117 to take over control of the crank 108 while the fluid in cylinder 118' flows to tank through conduit 273, groove 243, groove 239, and the radial ports connecting the same to longitudinal passage 241, and thence to the tank through 275. The screw 119 for piston 117 is adjusted to permit of increased shift of the control member 51 and hence increased displacement of the pump. This change in the position of the valve 236 does not affect the piston 122 and hence the motor continues to operate at a feed rate, but at one somewhat higher than the feed rate previously described.

The valve 192 might, of course, have been shifted to the left to the position shown in Fig. 4 with the same results throughout except that control fluid would have been supplied to the conduit 269 and hence to the right hand end of cylinder 57, with the result that the direction of discharge of fluid from the pump P would have been reversed with respect to the direction of discharge described in connection with shift of the valve 192 to the right.

When the valve 192 is shifted to the traverse positions, shown in Figs. 5 and 6, the wobblers of both the pump and the motor are adjusted to provide for maximum rate of operation of the motor and the feed valve means 235, and the pistons 117 and 118 controlled thereby are rendered inoperative. As clearly seen in Figs. 5 and 6, control fluid is still supplied to the cylinder 57 so as to cause the wobbler to be urged toward engagement with the control member 51. With the valve shifted to the right, as shown in Fig. 5, fluid is supplied to the left hand end of the cylinder 57 through conduit 268, while the right hand end is connected to tank through the conduit 269 the same as described for the feed position of Fig. 3. When the valve is shifted to the left, as shown in Fig. 6, fluid is supplied to the right hand end of the cylinder 57 through the conduit 269 to effect reverse operation of the pump.

Though fluid is thus continued to be supplied to the cylinder 57, the conduit 271 is in both traverse positions of the valve connected to tank. In Fig. 5 this connection to tank is through the recess 206 and longitudinal passage 205, while in Fig. 6 it is through recess 207 and longitudinal passage 205. With conduit 271 connected to tank, conduit 272 is likewise connected to tank and thus there is no fluid pressure in either the cylinder 117 or the cylinder 118, since in either position of the valve 236 one cylinder will be connected directly to tank through the conduit 275, while the other cylinder will be connected to tank through the conduit 272 and conduit 271. The pistons 117 and 118 thus will exercise no restraint on the crank 108, with the result that the pressure in the cylinder 57 will overcome the reaction of the pistons on the wobbler and the pre-loading of the wobbler to shift the control member 51 to its extreme left position wherein the wobbler is positioned for maximum displacement of the pump.

Fluid is, however, supplied to the right hand end of the cylinder 121 through conduit 270 which, in the position of the valve shown in Fig. 5, communicates with the longitudinal passage 200 through the recess 203 and, in the position of the valve shown in Fig. 6, communicates with the passage through the recess 204. Thus the piston 122 will be shifted to the left, as viewed in Fig. 1, and the wobbler 94 will be adjusted to a minimum stroke position. This minimum stroke of the motor, coupled with the maximum displacement of the pump, will produce a traverse rate of operation of the motor for either direction of operation thereof.

Provision is made for the shift of the valve 192 hydraulically from one side of neutral through neutral to traverse position without having fluid pressure constantly acting on the ends of the valve 192. To that end, the plunger valves 214 and 215 are provided and are connected in a unique circuit. If the valve is to be shifted from a position to the left of neutral to a traverse position at the right of neutral, to reverse the direction of operation of the motor, this may be effected hydraulically by depression of the plunger valve 215, such depression usually being effected automatically by dog means on a table or the like driven by the motor. As best seen in Fig. 5, when the valve 218 of the valve means 215 is depressed, control fluid in the conduit 251 is, through recess 222, supplied to the groove 226, thence by conduit 230 and recess 221 of the valve means 214 to conduit 266, discharging to the left hand end of the bore 191. The right hand end of the bore 191 is connected by a conduit 267 to groove 227 of the valve means 215 and from thence through recess 221, groove 228, conduits 231, 232 and 233 to the chamber 213, and thence to tank. Thus the control fluid supplied to the left hand end of the bore 191 will shift the valve to its traverse position to the right of neutral, as shown in Fig. 5. When the valve 218 of the valve means 215 is returned to its normal projecting position, conduit 251 is cut off from the conduit 230, disrupting the supply of control fluid to the conduit 266 and in turn connecting the conduit 230 to the conduit 267 which has been connected to tank, and thus interconnecting the ends of the bore 191. The fluid will be at no pressure but can flow back and forth from one end of the bore to the other, to permit manual shifting of the valve 192. It is believed apparent that for a shift of the valve 192 from a position at the right of neutral to its traverse position at the left of neutral it is only necessary to depress the valve 218 of the valve means 214. Control fluid will then be supplied to the right hand end of the bore 191 through conduits 251 and 229, the latter of which is now bridged with the conduit 230 by the recess 222 of valve 214 so that the control fluid may then return to the valve means 215 where it flows through recess 221 to conduit 267 to the right hand end of the bore. The left hand end of the bore is connected to tank in the same manner as described for the right hand end in Fig. 5, but through the valve means 214.

I claim as my invention:

1. A pumping mechanism comprising, in combination a main pump, an auxiliary pump, for supplying make-up fluid to the main pump, and means for controlling the pressure of the make-up fluid, said last mentioned means being responsive to the pressure of the fluid discharged by said main pump for governing the pressure of the fluid discharged by said auxiliary pump.

2. A pumping mechanism comprising in combination a variable displacement main pump, fluid operated displacement control means therefor, an auxiliary pump for supplying control fluid to said displacement control means, and valve means responsive to the pressure of the fluid discharged by said main pump governing the pressure of the fluid discharged by said auxiliary pump to said control means.

3. A pumping mechanism comprising, in combination, a main pump, control means therefor, an auxiliary pump, a discharge line leading from said auxiliary pump to the main pump control means, and by-pass valve means connected to said discharge line operable to maintain a predetermined pressure of the fluid in the discharge line and including means subjected to the pressure of said main pump urging said valve means to increase the pressure maintained in said discharge line.

4. A pumping mechanism comprising, in combination, a main pump, hydraulically actuated means for controlling the output thereof, an auxiliary pump, a discharge line leading from said auxiliary pump to said hydraulically actuated means, a by-pass valve means connected to said discharge line and having an open and a closed position, the fluid in said discharge line acting on said valve means to open the same, and means connecting said main pump to said valve means whereby the main pump pressure urges said valve means toward closed position.

5. In a hydraulic circuit, a main pump, an auxiliary pump, a discharge line leading from said auxiliary pump, a by-pass valve means connected to said discharge line and having an open and a closed position, the fluid in said discharge line acting on said valve means to open the same, means acting on said valve means to maintain a constant pressure in said discharge line, and means for additionally subjecting said valve means to the discharge pressure of said main pump to increase the pressure maintained in said discharge line with an increase in the discharge pressure of said main pump.

6. In a hydraulic circuit, a reversible main pump having a pair of ports alternatively operable as discharge ports, an auxiliary pump, a discharge line leading from said auxiliary pump, a by-pass valve means connected to said discharge line and having an open and a closed position, the fluid in said discharge line acting on said valve means to open the same, a plunger having two pressure surfaces of equal area and operable when either surface is subject to pressure to urge said valve means to closed position, a conduit leading from one of the ports in said main pump to one of said pressure surfaces, and a second conduit leading from the other port in said main pump to the remaining pressure surface.

7. In a hydraulic circuit, a variable displacement pump, means governing the displacement of said pump, and means operable to increase the displacement of said pump with an increase in the working pressure of said pump.

8. In a hydraulic circuit, a variable displacement pump, means governing the displacement of said pump, including hydraulically actuated means operable when supplied with fluid under pressure to tend to increase the displacement of the pump, and means supplying fluid to said hydraulically actuated means including means for increasing the pressure of the fluid supplied with an increase in the working pressure of said pump.

9. In a hydraulic circuit, a variable displacement pump having a wobbler, means governing the displacement of said pump including piston and cylinder means connected with the wobbler and operable when supplied with fluid under pressure to urge the wobbler toward increased displacement, an auxiliary pump for supplying control fluid to said piston and cylinder means, and by-pass valve means responsive to the working pressure of said first mentioned pump controlling the pressure of said auxiliary pump to increase the pressure of the control fluid with an increase in the working pressure of said first mentioned pump.

10. In a hydraulic circuit, a variable displacement pump having a wobbler, means governing the displacement of said pump including piston and cylinder means connected with the wobbler and operable when supplied with fluid under pressure to urge the wobbler toward increased displacement, means placing a constant pre-load on the wobbler tending to restore the same to zero displacement, an auxiliary pump for supplying control fluid to said piston and cylinder means, and by-pass valve means responsive to the working pressure of said first mentioned pump controlling the pressure of said auxiliary pump to increase the pressure of the control fluid with an increase in the working pressure of said first mentioned pump.

11. In a hydraulic circuit, a variable displacement pump having a pivotally mounted wobbler, a control member engaging the wobbler to determine the tilt thereof, a first hydraulic device acting through said member to urge said wobbler to no-stroke position, a second hydraulic device connected with said wobbler and operable when supplied with fluid under pressure to urge said wobbler toward increased displacement of the pump, means for supplying fluid to said first hydraulic device at constant pressure to place a constant pre-load on the wobbler, and means for supplying fluid to said second hydraulic device at pressures increasing with increases in the working pressure of said first mentioned pump.

12. In a hydraulic circuit, a variable displacement pump having a pivotally mounted wobbler, a control member engaging the wobbler to determine the tilt thereof, a first hydraulic device acting through said member to urge said wobbler to no-stroke position, a second hydraulic device connected with said wobbler and operable when supplied with fluid under pressure to urge said wobbler toward increased displacement of the pump, an auxiliary pump for supplying control fluid, by-pass valve means governing the pressure of the fluid supplied by said auxiliary pump to said second hydraulic device, said by-pass valve means being subjected to the working pressure of the first mentioned pump and increasing the pressure of the control fluid with increases in working pressure of the first mentioned pump, and a pressure reducing valve for maintaining constant the pressure of the control fluid supplied to said first hydraulic device.

13. In a hydraulic circuit, a variable displacement pump having a plurality of annularly arranged piston and cylinder devices, a drive shaft and a wobbler pivotally mounted on said shaft and engaging the pistons of said devices, the reaction of the pistons on said wobbler tending to return the same to no-stroke position, a control member determining the tilt of said wobbler, a hydraulic device operable when supplied with

fluid under pressure to urge said wobbler toward a position of increased displacement of said pump, and means for supplying control fluid to said hydraulic device including means for increasing the pressure of the control fluid with an increase in the working pressure of said pump, the increase in force of said hydraulic device by the increase in control pressure being equal to the increased reaction of the pistons on said wobbler.

14. In a hydraulic circuit, a variable displacement pump having a plurality of annularly arranged piston and cylinder devices, a drive shaft and a wobbler pivotally mounted on said shaft and engaging the pistons of said devices, the reaction of the pistons on said wobbler tending to return the same to no-stroke position, a control member determining the tilt of said wobbler, a first hydraulic device acting through said control member to urge said wobbler to no-stroke position, a second hydraulic device operable when supplied with fluid under pressure to urge said wobbler toward a position of increased displacement of said pump, an auxiliary pump supplying control fluid to both hydraulic devices, a by-pass valve determining the pressure of the control fluid, a reducing valve determining the pressure of the control fluid supplied to said first hydraulic device, the force of said second hydraulic device exceeding the sum of the forces of said first hydraulic device and the pistons, said by-pass valve means being subjected to the working pressure of said first mentioned pump and operating to increase the pressure of the control fluid with an increase in the working pressure of said pump, the increase in force of said hydraulic device by the increase in control pressure being equal to the increased reaction of the pistons on said wobbler.

15. In a hydraulic circuit, a variable displacement pump having a plurality of annularly arranged piston and cylinder devices, a drive shaft and a wobbler pivotally mounted on said shaft and engaging the pistons of said device, the reaction of the pistons on said wobbler tending to return the same to no-stroke position, a control member determining the tilt of said wobbler, a first hydraulic device acting through said control member to urge said wobbler to no-stroke position, a second hydraulic device operable when supplied with fluid under pressure to urge said wobbler toward a position of increased displacement of said pump, an auxiliary pump supplying control fluid to both hydraulic devices, a by-pass valve determining the pressure of the control fluid, a reducing valve determining the pressure of the control fluid supplied to said first hydraulic device, the force of said second hydraulic device exceeding the sum of the forces of said

first hydraulic device and the pistons, said by-pass valve means being subjected to the working pressure of said first mentioned pump and operating to increase the pressure of the control fluid with an increase in the working pressure of said pump, the increase in force of said hydraulic device by the increase in control pressure being equal to the increased reaction of the pistons on said wobbler, and means for determining the position of said control member.

16. In a hydraulic circuit, a pump for discharging operating fluid, hydraulically actuated means for reversing the direction of discharge of said pump, means supplying control fluid and valve means governing the control fluid comprising a hydraulically shiftable valve and a plurality of plunger valves governing the control fluid normally to maintain said shiftable valve under no pressure and to supply fluid under pressure for shifting the shiftable valve only when a plunger valve is actuated.

17. In a hydraulic circuit, a pump for discharging operating fluid, hydraulically actuated means for reversing the direction of discharge of said pump, means supplying control fluid and valve means governing the control fluid comprising a valve bore, a cylindrical valve slidable in the bore and having a neutral position and a shifted position on either side of neutral, and a pair of plunger valve means each having a normal position and a shifted position and each connected to control the supply of control fluid to one end of the valve bore and the exhaust of fluid from the opposite end of the valve bore, said plunger valve means in normal position interconnecting the ends of the valve bore.

18. In a hydraulic circuit, a pump for discharging operating fluid, hydraulically actuated means for reversing the direction of discharge of said pump, means supplying control fluid and valve means governing the control fluid comprising a valve bore, a cylindrical valve slidable in the bore and having a neutral position and a shifted position on either side of neutral, and a pair of governing valve means each connected to the supply of control fluid and additionally connected to one another, one of said governing valve means connected to one end of said valve bore and the other valve means connected to the opposite end of said valve bore, each of said valve means having a normal position interconnecting the ends of the valve bore when both governing valve means are in normal position, and each having a shifted position connecting one end of the valve bore to the supply of control fluid through the other valve means and the opposite end of the valve bore to tank.

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