United States Patent

[11] 3,601,986

[72] Inventor **Lester J. Becker**
5605 Franconia Road, Alexandria, Va. 22301

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[54] **HYDRAULIC CONTROL SYSTEM**
5 Claims, 12 Drawing Figs.

[52] U.S. Cl. ..... **60/52 VS**, 60/53 R, 60/53 B, 417/426
[51] **Int. Cl.** **F15b 15/18**, F15b 18/00
[50] **Field of Search** ..... 60/53 B, 53 R, 52 VS; 417/426, 429

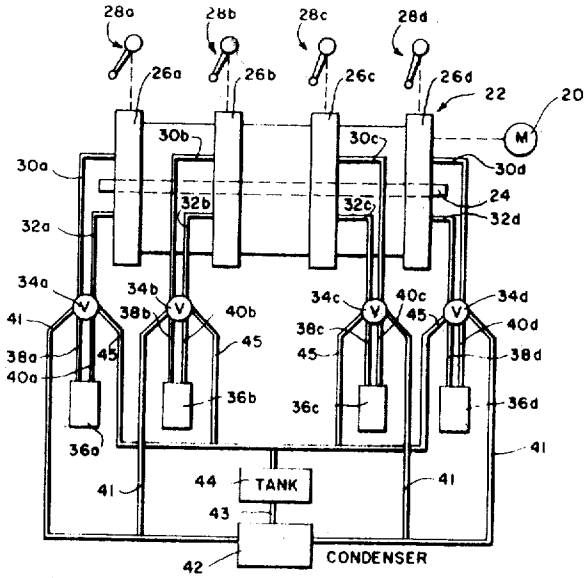
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Primary Examiner—Edgar W. Geoghegan
Attorney—Robert I. Lainof

ABSTRACT: A hydraulic control unit includes a plurality of radial pump units driven by a common drive means. Each of the pump units is provided with an individual control assembly in the form of a control lever for rotating a cam which adjusts the eccentricity of a guide ring coupled to the radial pistons of a pump unit. In this way, the direction and magnitude of flow from the pump is controlled, being fed to or from the pump through a pair of conduits. The conduits are connected to a valve which, in response to the direction of flow in the conduits, is shifted to direct fluid flow in one of two directions through a hydraulic work unit. The valve also serves to direct fluid received from the work unit to a common condenser.



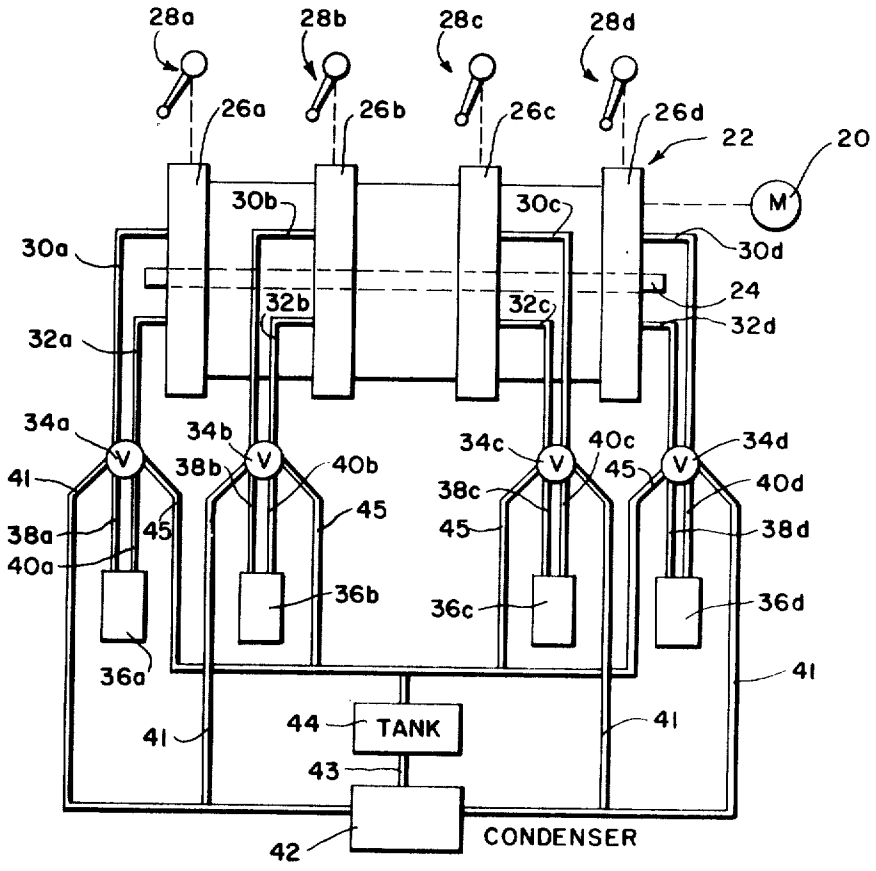


FIG. 1

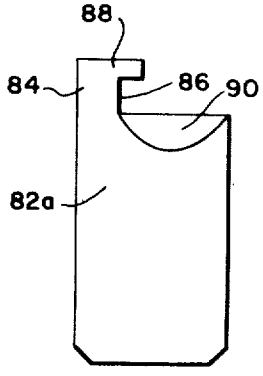


FIG. 5

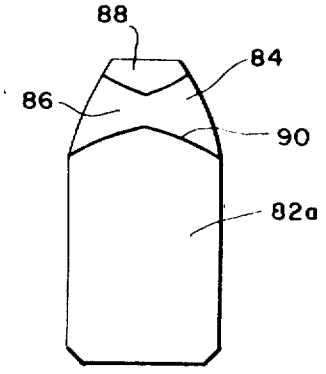


FIG. 6

INVENTOR
LESTER J. BECKER

BY Robert A. Parisi

ATTORNEY

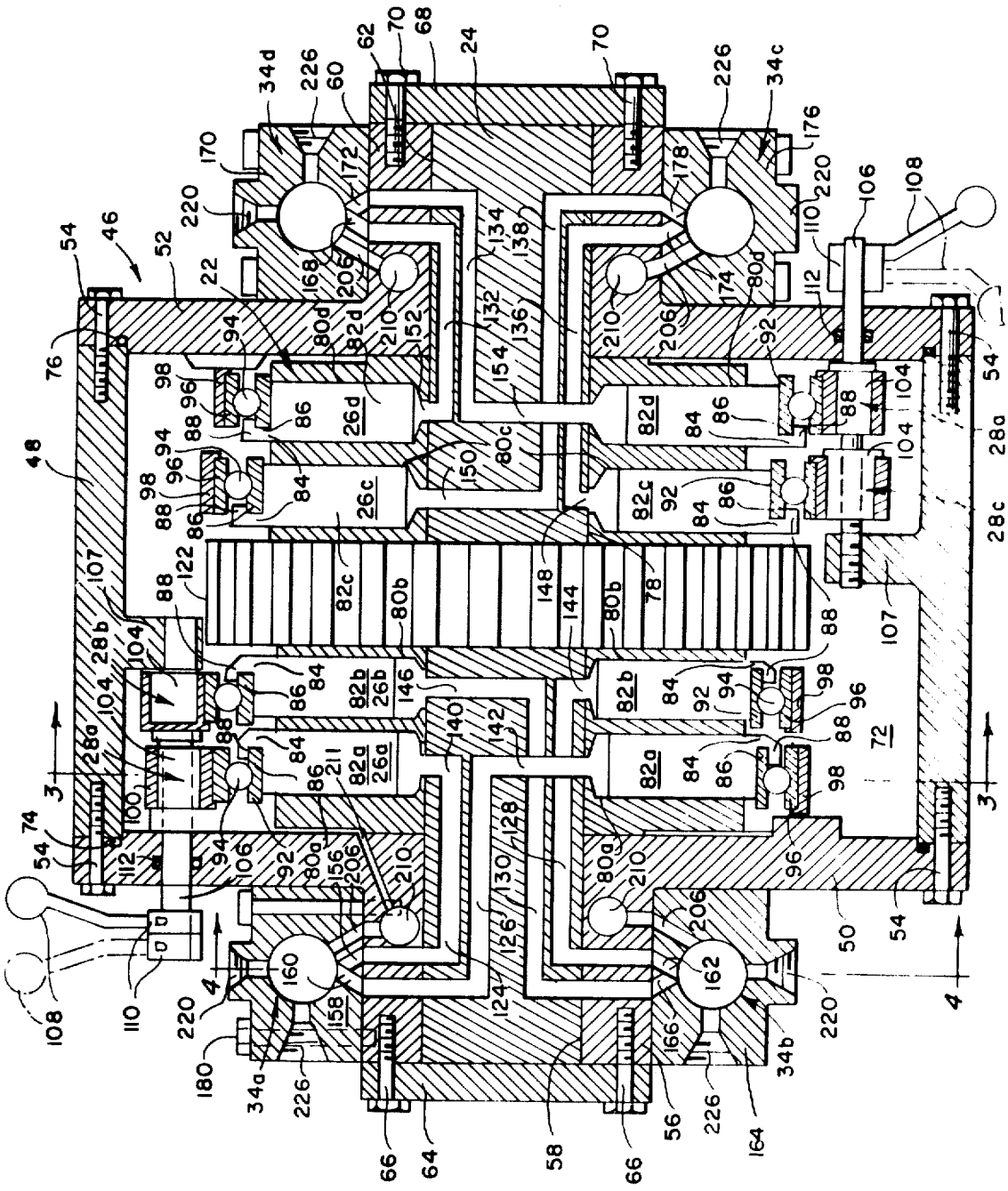


FIG. 2

INVENTOR
LESTER J. BECKER

BY Robert D. Sainsbury

ATTORNEY

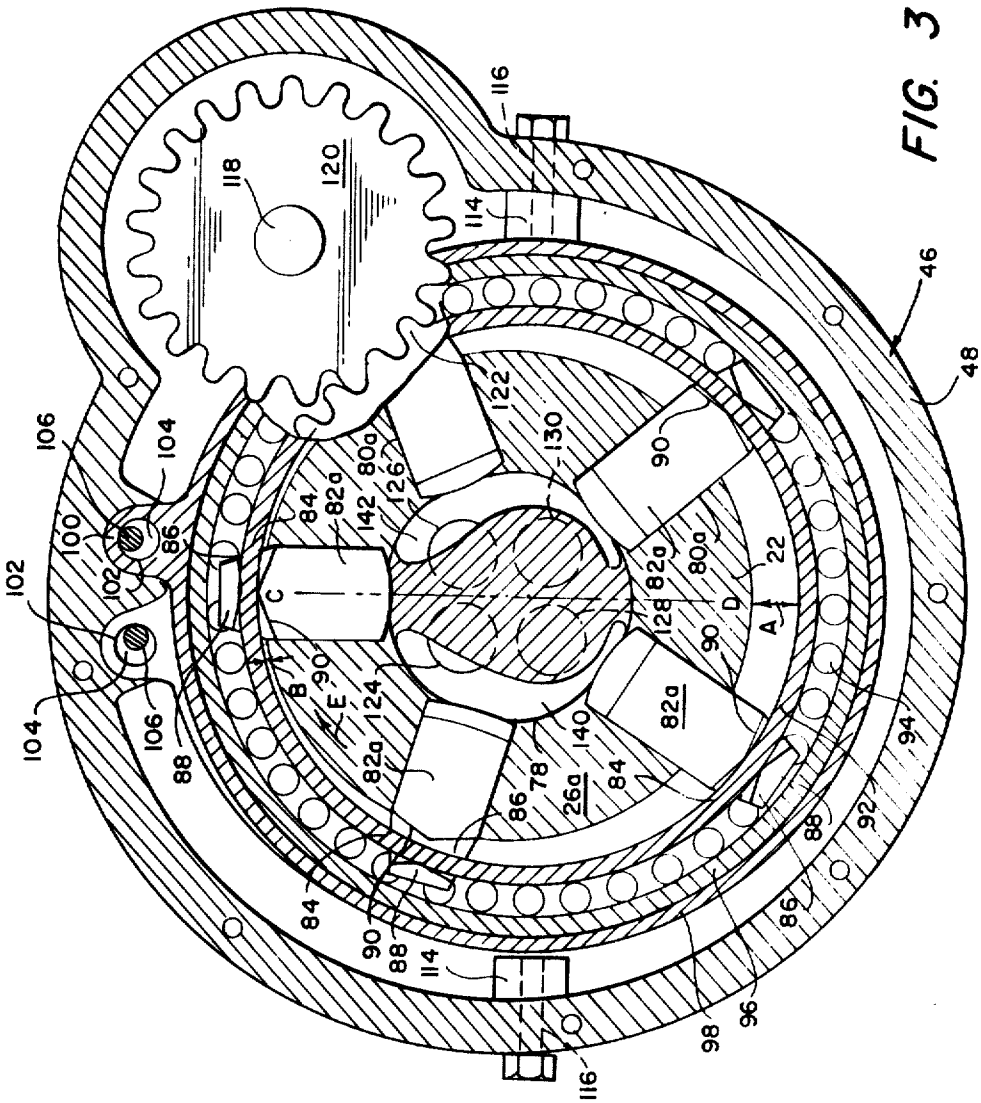


FIG. 3

INVENTOR
LESTER J. BECKER

BY Robert J. Lawson

ATTORNEY

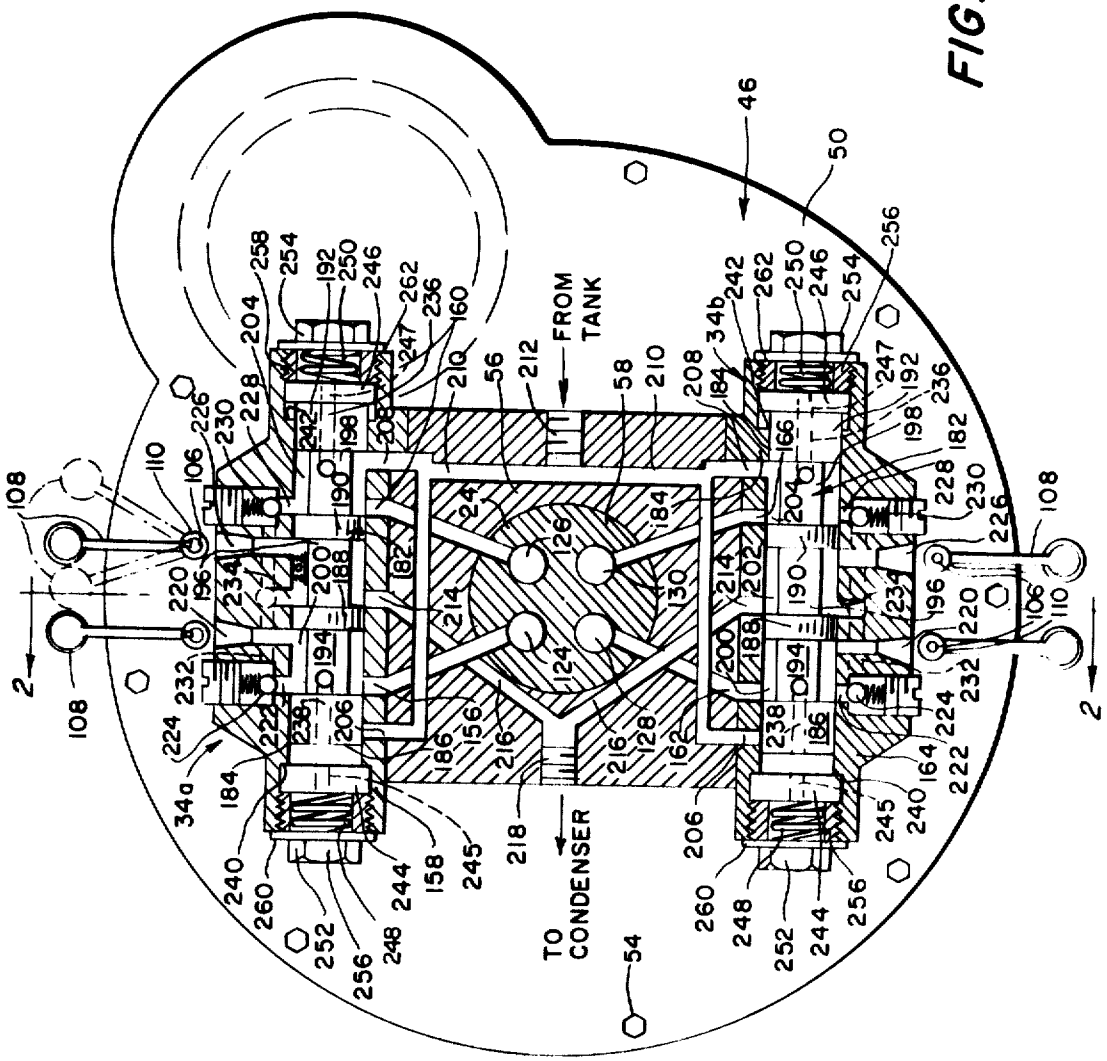


FIG. 4

INVENTOR
LESTER J. BECKER
BY Robert D. Sainsf
ATTORNEY

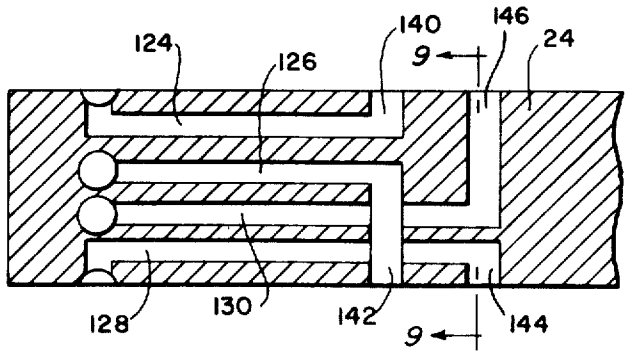


FIG. 8

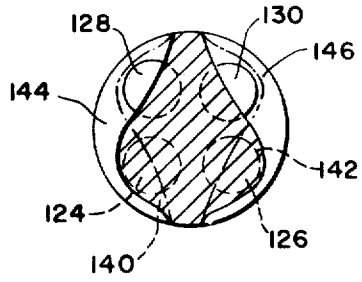


FIG. 9

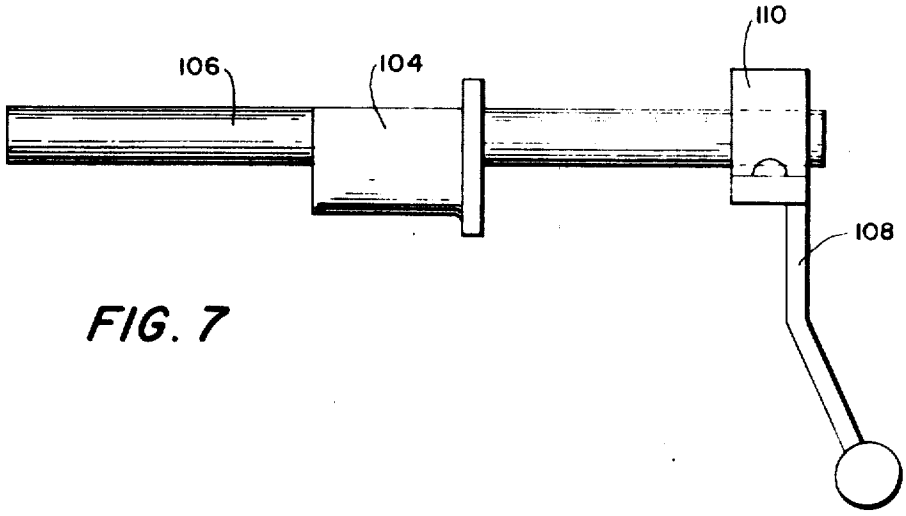


FIG. 7

INVENTOR
LESTER J. BECKER

BY Robert J. Lainoff
ATTORNEY

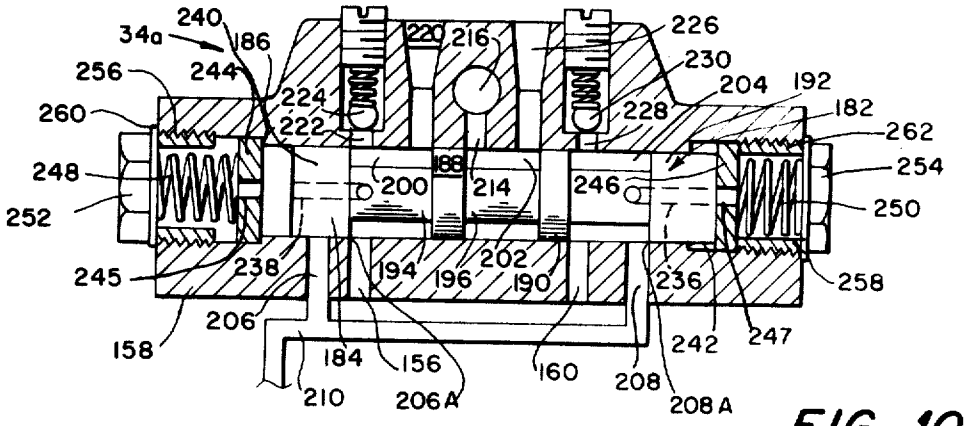


FIG. 10

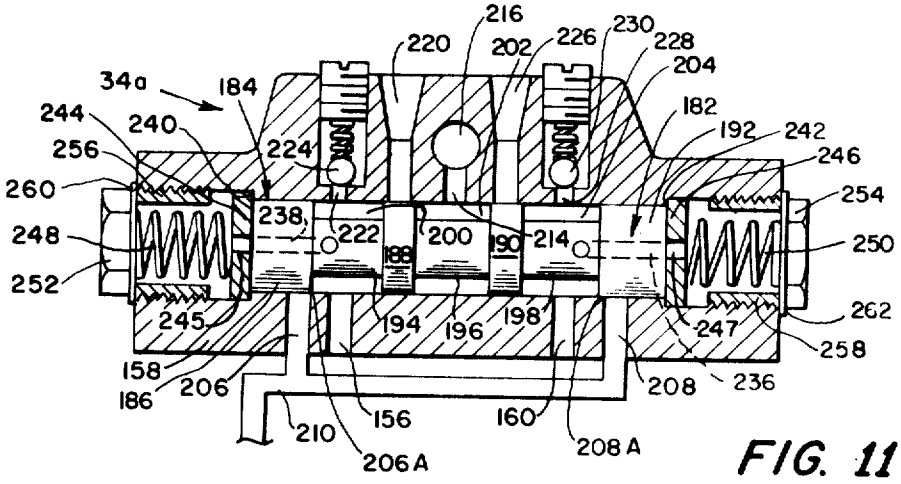


FIG. 11

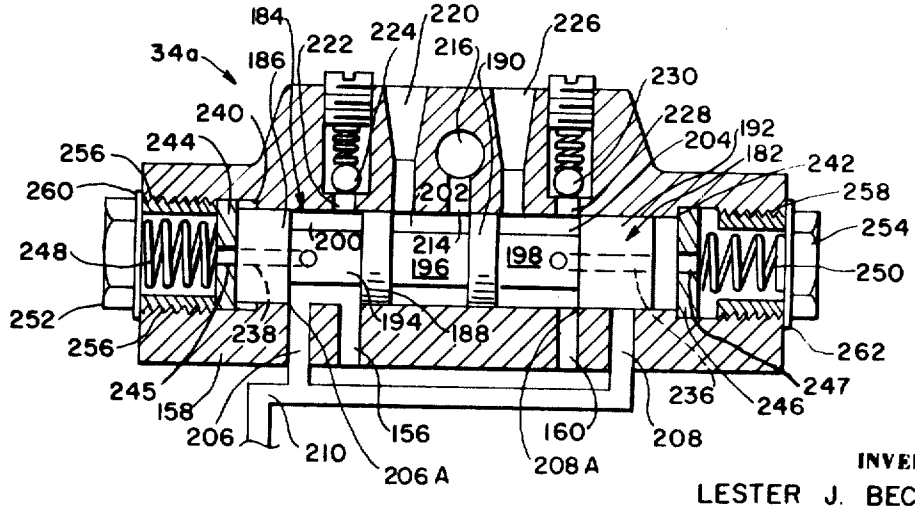


FIG. 12

INVENTOR
LESTER J. BECKER

BY Robert J. Lanoff
ATTORNEY

HYDRAULIC CONTROL SYSTEM

BACKGROUND OF THE INVENTION

This invention relates to hydraulic control systems and, more particularly, to hydraulic systems employing radial pump units.

It is frequently desirable in hydraulic control systems to provide a variable quantity of fluid under pressure to a hydraulic work unit, such as a hydraulic cylinder, motor, or the like. To this end, it has been suggested in the prior art that a variable delivery pump be employed for providing the variable flow of hydraulic fluid. Radial piston pumps have been particularly suitable for this purpose. Such pumps employ a rotor having a plurality of radial bores within which pistons are provided in conjunction with guide means for regulating the stroke of the pistons. If the guide means is made eccentric with respect to the axis of rotation of the rotor, the pistons will be caused to reciprocate radially of the rotor within the bores to effect a pump action. The extent of eccentricity will regulate the volume of flow provided by the pump.

In prior art hydraulic control systems employing variable delivery pumps of the radial-piston pump type, it was necessary, where a plurality of hydraulic work units were employed, to provide a plurality of radial pumps with separate drive means for each pump; or, when a single drive motor was employed, it was necessary to employ elaborate gearing to drive each of the radial pumps separately. It is also difficult in such prior art systems to control the direction of fluid flow to the hydraulic work unit from the radial pump units. In addition, the means provided for adjusting the eccentricity of prior art radial pump units have tended to be unduly complex or inconvenient to control.

SUMMARY OF THE INVENTION

It is accordingly an object of the present invention to provide an improved hydraulic control system employing radial pump units.

More particularly, it is an object of the invention to provide a hydraulic control system employing radial pump units which is versatile in application, simple to control, easy to maintain with a minimum inventory of spare parts, and economical.

It is a further object of the invention to provide a hydraulic control system in which a plurality of radial pump units are driven on a single shaft and powered by a single prime mover rotating in one direction. An additional object relates to the provision, in a system of this character, of control means, capable of remote operation, for independently controlling the radial pump units for variable output in either direction. A related object is the provision of a single control unit for each radial pump unit for controlling the direction of flow from the pump unit regardless of the direction of prime mover rotation and the direction of flow from the remaining pump units and for acting as a metering valve for flow control so that flow can be controlled from zero to full capacity of the pump unit.

Another object is the provision of a control valve in association with a radial pump unit for automatically directing fluid through a hydraulic work unit for the proper direction as indicated by the control. A related object is the provision of a control valve in a system of the aforementioned character which acts as a locking valve to hold a cylinder of a hydraulic work unit in any given position.

Briefly, according to the present invention, a single prime mover drives rotor means including a plurality of radial pump units, each having a plurality of radial bores and a piston in each bore. Each of the radial pump units has individual control means for adjusting the radial stroke of the pistons of each unit so that the direction and magnitude of fluid flow in a pair of conduits leading to and from the radial pump unit is controlled independently of the direction and magnitude of flow in conduits associated with the remaining pump units and the direction of rotation of the rotor means. The system includes special valve means coupled to the conduits including a valve body normally biased to a midposition and responsive to fluid flowing from one of the conduits for directing fluid through a hydraulic work unit in one direction and responsive to fluid flowing from the other of the conduits for directing the fluid through the hydraulic work unit in the opposite direction. More specifically, the special valve includes a valve body or spool having a plurality of valve recesses and a pair of end chambers associated with springs which bias the valve body and maintain it in a midposition in the absence of fluid flowing from either conduit. When fluid is received from either conduit, the pressure thereof is applied against the valve body to shift it and open a fluid path to the hydraulic work unit in the desired direction. In order to control the magnitude and the direction of fluid flow from each of the radial pump units, individual control means comprising a control shaft and a cam for adjusting the eccentricity of a guide ring in the pump unit is provided.

The foregoing and other objects, advantages, and features of the invention and the manner in which the same are accomplished will become more readily apparent upon consideration of the following detailed description of the invention when taken in conjunction with the accompanying drawings, which illustrate a preferred and exemplary embodiment.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a schematic diagram of a hydraulic control system of the invention;

FIG. 2 is a schematic section view of a hydraulic control unit of the invention generally taken along line 2—2 of FIG. 4 with conduits and control assemblies displaced to aid in the explanation of the invention;

FIG. 3 is a schematic section view taken generally along line 3—3 of FIG. 2;

FIG. 4 is a schematic section view taken generally along line 4—4 of FIG. 2;

FIG. 5 is a side view of a piston of the invention;

FIG. 6 is a front view of the piston of FIG. 5;

FIG. 7 is a view of a control assembly of the invention;

FIG. 8 is a schematic partial longitudinal section view of the shaft of the invention with conduits displaced to aid in the explanation of the invention;

FIG. 9 is a section view taken generally along line 9—9 of FIG. 8;

FIG. 10 is a schematic section view of a valve unit of the invention in a first position;

FIG. 11 is a schematic section view of the valve unit of FIG. 10 in a second position; and

FIG. 12 is a schematic section view of the valve unit of FIG. 10 in a third position.

DETAILED DESCRIPTION

Referring to FIG. 1, it will be seen that a hydraulic control system of the invention comprises a single drive means or prime mover 20 which drives a single rotor means 22 about a single shaft 24. A plurality of radial pump units 26*a*, 26*b*, 26*c*, and 26*d* are included in rotor means 22 and are driven therewith. The direction and magnitude of fluid flow from each of the pump units is controlled by corresponding control assemblies 28*a*, 28*b*, 28*c*, and 28*d* which, as will be presently explained, individually regulate the pump units independently of the remaining pump units and the direction of rotation of the rotor means. Pairs of conduits 30*a* and 32*a*, 30*b* and 32*b*, 30*c* and 32*c*, and 30*d* connect radial pump units 26*a*, 26*b*, 26*c* and 26*d*, respectively, with corresponding valve units 34*a*, 34*b*, 34*c* and 34*d*. The position of the control assembly for each pump unit will determine whether there will be any fluid flow and, if so, the direction of flow in the corresponding conduits. In any case, the corresponding valve will automatically, in response to the direction of flow in the conduits control the direction of fluid flow to corresponding work units 36*a*, 36*b*, 36*c* and 36*d* through pairs of fluid paths 38*a* and 40*a*, 38*b* and 40*b*, 38*c* and 40*c*, and 38*d* and 40*d*, respectively, in a manner to be presently described.

After fluid is returned from a hydraulic work unit, the fluid will be directed by the corresponding valve to a condenser **42** through a condenser return conduit **41**. The purpose of the condenser is to cool the oil and return it through conduit **43** to an oil storage tank **44**. Fluid is taken, in turn, from fluid storage tank **44** through conduits **45** and valves **34***a*, **34***b*, **34***c* and **34***d* to the corresponding radial pump units through one of the corresponding conduits **30***a*, **30***b*, **30***c* and **30***d* or **32***a*, **32***b*, **32***c* and **32***d*, depending upon the setting of the corresponding control assembly. Should, however, the control assembly for a particular radial pump unit be in its neutral position, no fluid will flow through either of the corresponding conduits; and the corresponding valve will, as will be presently explained, serve as a locking valve to maintain the corresponding hydraulic work unit in the position to which it was previously adjusted.

Turning to FIG. **2**, it will be seen that a hydraulic control unit of the invention includes a closed housing **46**. The housing includes a cylindrical outer wall **48**, the ends of which are closed by circular end walls **50** and **52**, being suitably secured thereto by means of bolts **54**. End wall **50** has a central extension **56** extending outwardly therefrom and providing a central bore **58**. Likewise, end wall **52** is provided with a central extension **60** extending outwardly in the opposite direction and providing a central bore **62** of the same internal diameter as bore **58**. It will be noted that shaft **24** is received in bores **58** and **62** and extends therebetween. It is to be understood that shaft **24** is relatively stationary with respect to housing **46**, and appropriate detent means may be provided for this purpose. In order to seal the ends of housing **46**, an end plate **64** is secured to the end of end wall extension **56** by means of bolts **66**, and an end plate **68** is secured to the end of end wall extension **60** by means of bolts **70**. Since it is desirable that the space **72** within housing **46** be filled with oil to surround the operating parts, appropriate sealing gaskets **74** and **76** are provided between end wall **50** and cylindrical outer wall **48** and between end wall **52** and cylindrical outer wall **48**, respectively. Similar sealing gaskets (not shown) may be provided between end plate **64** and end wall extension **56** and between end plate **68** and end wall extension **60**.

As will be noted from FIGS. **2** and **3**, rotor **22** is mounted for rotation on stationary shaft **24** and, for this purpose, includes a central bore **78** which is received on shaft **24**. Suitable bearing means (not shown) may be provided between rotor **22** and shaft **24** for facilitating the rotation. As particularly shown in FIG. **3**, radial pump unit **26***a* comprises five radial bores **80***a* extending radially outwardly in substantially the same plane from central bore **78**. From FIG. **2** it will be seen that the remaining radial pump units **26***b*, **26***c*, and **26***d* contain substantially identical radial bores **80***b*, **80***c*, and **80***d*, respectively. Each of the radial bores receives a piston mounted for reciprocation therein. Referring to FIG. **3**, for example, it will be seen that radial pump unit **26***a* comprises pistons **82***a* within radial bores **80***a*. In like manner, as shown in FIG. **2**, pistons **82***b*, **82***c* and **82***d* are received in bores **80***b*, **80***c* and **80***d*, respectively.

As shown in FIGS. **5** and **6**, each of the pistons is provided with a piston extension **84** providing a guide groove **86** defined by an upper lip **88** and inclined surfaces **90** on the upper end of the main portion of the piston body. Guide grooves **86** are received on a guide ring **92** which also forms the inner race of a ball bearing **94**, being freely rotatable thereon. The outer race **96** of the ball bearing is relatively stationary and is received within an adjusting ring **98**.

The stroke of the pistons is regulated by the degree of eccentricity of guide ring **92** with respect to the axis of rotation of rotor **22**. When guide ring **92** is concentric with the axis of rotation of rotor **22**, the guide groove **86** of the piston will be equidistant from the axis of rotation for all points in the rotation of the rotor; and the pistons will not reciprocate within the bores as the rotor rotates. On the other hand, if guide ring **92** is shifted to become eccentric of the axis of rotation, at different points in the rotary travel of rotor **22** the pistons will be shifted relative to the axis of rotation and will therefore reciprocate within the radial bores. In order to facilitate the adjustment of the eccentricity of guide ring **92**, the adjusting rings **98** have adjusting ring extensions **100** provided with adjusting ring extension bores **102** which are dimensioned to receive control cams **104** mounted on control shafts **106**. As is most clearly shown in FIG. **7**, a control lever **108** is secured by means of a sleeve **110** on one end of control shaft **106**. Referring to FIG. **2**, it will be noted that control shaft **106** extends through one of end walls **50** and **52** and is associated with an appropriate sealing gasket **112**. The other end of shaft **106** is journaled in a lug **107** projecting from the inner surface of wall **48**. As will be noted from FIG. **2**, each of radial piston units **26***a*, **26***b*, **26***c* and **26***d* is provided with a corresponding control assembly **28***a*, **28***b*, **28***c* and **28***d* comprising a guide ring **92**, a ball bearing **94**, an outer ball bearing race **96**, an adjusting ring **98**, and adjusting ring extension **100**, an adjusting ring extension bore **102**, a control cam **104**, a control shaft **106**, a lug **107**, a control lever **108**, a control lever sleeve **110**, and a control shaft gasket **112**. Since all the control levers **108** would not normally be seen in the view of FIG. **2**, some of these have been shown in phantom lines for purposes of illustration. Thus, it will be apparent that the guide rings of the respective radial pump assemblies may be individually adjusted independently of the adjustment of the remaining guide rings. Although, as illustrated, control levers **108** are to be actuated manually, it is to be understood that the positions of the control levers may be adjusted automatically by providing appropriate linkages to an automatic control system.

In order to limit lateral adjustment of adjusting rings **98** and to maintain them generally concentric of rotor **22**, stops **114** may be provided mounted on bolts **116** extending through the wall **48** of housing **46** on each side of the ring. Since stops **114** extend inwardly of wall **48** in close adjacency to adjusting ring **98**, they limit the lateral movement thereof, permitting, however, limited adjustment by means of cams **104**. Although only a pair of stops **114** are shown in FIG. **3**, it is to be understood that two such stops are provided for each of the adjusting rings associated with each of the radial pump units.

As already mentioned, rotor **22** is caused to be rotated by a prime mover or motor **20**. To this end, as shown most clearly in FIG. **3**, a driveshaft **118** is driven by prime mover **20** and drives a driving gear **120**. Drive gear **120** meshes with a rotor gear **122** (See FIG. **2**) forming an integral part of rotor **22**. Due to the unique control assemblies employed with the several radial pump units, there is no need to provide directional control for the prime mover **20** which may drive drive shaft **119** continually in one direction and at a constant speed. All adjustments as to magnitude of flow and direction of flow will be accomplished by suitable adjustment of the corresponding control assembly of a particular radial pump unit independently of the adjustments of the remaining radial pump units.

The manner in which the hydraulic fluid flows to and from the radial pump units will now be described. As will be seen most particularly in FIGS. **2**, **3**, **8** and **9**, shaft **24** is provided with a plurality of conduits leading to and from the radial pump units. A first pair of conduits **124** and **126** at the left-hand end of shaft **24** are associated with radial pump unit **26***a*. A second pair of conduits **128** and **130** at the same end of the shaft are associated with radial pump unit **26***b*. In like manner, at the opposite end of shaft **24** (see FIG. **2**) conduits **132** and **134** lead to and from radial pump unit **26***d*, while conduits **136** and **138** are associated with radial pump unit **26***c*. Conduit **124** leads to a port **140** which extends a substantial distance (nearly halfway) around the circumference of shaft **24**. Similarly, conduit **126** terminates in a port **142** which extends for the same distance about the remaining half of the circumferential periphery of shaft **24**. Ports **140** and **142** are at substantially the same axial position along shaft **24**, thus communicating with the radial bores **80***a* as the rotor rotates thereover. In like manner, conduit **128** terminates in port **144** extending about nearly one half of the periphery of shaft **24** adjacent to the radial bores **80***b* of radial pump unit **26***b*, and

conduit 130 terminates in port 146 extending over nearly the remaining half of the periphery of shaft 24 adjacent to radial bores 80*b*. As will be apparent from FIG. 2, similar ports 148 and 150 are in communication with conduits 136 and 138, respectively, and extend about substantial portions of the periphery of shaft 24 adjacent to the radial bores 80*c* of radial pump unit 26*c*; and ports 152 and 154 are terminations for conduits 132 and 134, respectively, and communicate with substantial portions of the periphery of shaft 24 adjacent radial ports 80*d* of radial pump unit 26 *d*.

The opposite ends of the conduits in shaft 24 communicate with one of the valves 34*a*, 34*b*, 34*c*, and 34*d*, as will be presently described. Thus, conduit 124 communicates with a port 156 extending through valve housing 158 of valve 34*a*, and conduit 126 communicates with a valve port 160 extending through valve housing 158. In like manner, conduit 128 leads to a valve port 162 extending through valve housing 164 of valve 34*b*, and conduit 130 leads to a valve port 166 extending through this valve housing. Similar connections are found for conduits 132, 134, 136 and 138. Conduit 132 extends to valve port 168 extending through valve housing 170 of valve 34*d* while conduit 134 is coupled to valve port 172 extending through valve housing 170. Conduit 136 leads to valve port 174 extending through valve housing 176 of valve 34*c*, and conduit 138 leads to valve port 178 in valve housing 176. The valve housings are suitably secured to the main housing 46 of the hydraulic control unit by means of bolts 180.

With particular reference to FIG. 4, it will be seen that valve 34*a* includes a spool 182 positioned within a valve chamber 184 provided inside valve housing 158. It will be noted that valve spool 182 comprises enlarged head portions 186, 188, 190 and 192 engaged with the cylindrical surface of valve chamber 184. Valve spool 182 also includes reduced diameter or neck portion 194 between valve heads 186 and 188, 196 between valve heads 188 and 190, and 198 between valve heads 190 and 192. These valve neck portions respectively provide valve recesses 200, 202, and 204 in valve spool 182. The valve housing 158 is also provided with a pair of ports 206 and 208 near each end of the valve chamber 184. These valve ports lead to a common conduit 210 which is connected to a port 212 adapted to be coupled by means of a suitable fitting to the line 45 leading from tank 44, whereby hydraulic fluid may be supplied to the valves from the tank. The valve 34*a* is also provided with a valve port 214 extending through valve housing 158 to valve chamber 184 at a central portion therealong. Valve port 214 communicates with a conduit 216 leading to a port 218 adapted to be connected by means of a suitable fitting to condenser return conduit 41 (see FIG. 1) leading to fluid condenser 42. As is evident from FIG. 2, a hole 211 is provided through end wall 50 from conduit 210 to the space 72 within housing 46 to allow pressure to escape from the system and prevent pressure build up in the housing which might cause the seals to blow.

Valve 34*a* is also provided with a valve port 220 extending through valve housing 158 which is adapted to be connected by means of an appropriate fitting to line 38*a* leading to or from a hydraulic work unit 36*a*. Near port 220 is a port 222 leading to a pop valve 224. An additional valve port 226 is provided through valve housing 158 and is adapted to be connected by means of a suitable fitting to line 40*a* leading to or from hydraulic work unit 36*a*. A valve port 228 is located near port 226 and leads to a pop valve 230. Pop valves 224 and 230 are responsive to excessive hydraulic pressure and are adapted to open a path through a conduit 232 to a valve port 234 communicating with valve recess 202, permitting fluid to be bypassed to condenser 42 through valve port 214 and conduit 216.

It is also to be noted that valve spool 182 is provided with a passageway 236 extending from neck 198 and valve recess 204 to the right-hand end of valve head 192. At the other end of valve spool 182 is a similar passage 238 extending from neck 194 and valve recess 200 to the left-hand end of valve head 186.

Valve chamber 184 includes enlarged end portions forming shoulders 240 and 242, and valve blocks 244 and 246 are respectively associated with shoulders 240 and 242 in the enlarged end portions of the chamber. Each of these valve blocks are biased by means of respective springs 248 and 250 into engagement with the corresponding shoulder. The springs bear respectively against the inner surfaces of end caps 252 and 254 which include threaded sleeves 256 and 258 respectively which engage internal threads within the valve housing 158. In order to properly position the end caps, they are provided with outwardly extending flanges 260 and 262, respectively, which abut against the corresponding ends of the valve housing 158. Valve block 244 is provided with an aperture 245 in alignment with passage 238, and valve block 246 has an aperture 247 in alignment with passage 236.

The normal position of the valve spool is shown in FIG. 11 with both of the valve blocks 244 and 246 biased into contact with the corresponding shoulders 240 and 242. It will be noted that in this position the valve ports 206 and 208 appear to be blocked by valve heads 186 and 192. However, in order to permit leak-by of fluid to valve recesses 200 and 204 from ports 206 and 208, valve heads 186 and 192 are slightly grooved as indicated at 206A and 208A. The purpose of this arrangement is to permit the pump unit to pick up oil to prime the unit as will become apparent when the operation of the hydraulic control systems is discussed in detail hereinbelow. The leak-bys also serve to keep the pump unit from building up the pressure in the system, permit instant fluid flow, prevent vacuums in the systems when the pump unit is idling, and prevent creeping of the corresponding work unit.

Each of the valves 34*a*, 34*b*, 34*c* and 34*d* are substantially identical and, accordingly, the remaining valves will not be described in detail. It is to be noted, however, that the same reference numerals are employed for the corresponding parts of the valves where they are seen in the drawings.

The operation of the hydraulic control system of the invention will be apparent from detailed consideration of the operation of one of the radial pump units 26*a* and its associated valve 34*a*, it being understood that the operation of the remaining radial pump units ad valves will be similar. Let it be assumed, at the outset, that the valve 34*a* is in its neutral, or starting position, as shown in FIG. 11. The valve spool 182 will be biased by springs 248 and 250 to its midposition. When the valve spool is in this position, valve blocks 244 and 246 are biased into engagement with corresponding shoulders 240 and 242 and abut the corresponding ends of the valve spool. Valve head 186 is positioned over valve port 206, and valve head 192 is positioned over valve port 208. Valve port 220 is closed by valve head 188, and valve port 226 is closed by valve head 190. However, valve ports 156 and 160 are open, communicating respectively with valve recesses 200 and 204. In like manner, valve port 222 is in communication with valve recess 200, and valve port 228 is in communication with valve recess 204. The path to condenser 42 through valve port 214 and conduit 216 is open from valve recess 202. If, at this time, the control lever 108 of control assembly 28*a* corresponding with radial pump unit 26*a* is in its neutral position, guide ring 92 will be concentric with rotor 22 and shaft 24. Under these circumstances, there will be no reciprocation of pump pistons 82*a*, and no pressure will be applied by the hydraulic fluid through conduit 124 and valve port 156 or through conduit 126 and valve port 160. The valve spool 182 will therefore remain in its midposition, as shown in FIG. 11. Since ports 220 and 226 will be closed by valve heads 188 and 190, the valve 34*a* will serve as a locking valve to hold the cylinder of hydraulic work unit 36*a* in its previously attained position.

If, now, control assembly 28*a* is adjusted by rotating its lever 108 to bring cam 104 into the position shown in FIG. 3 with respect to radial pump unit 26*a*, the distance A between the lower side of rotor 22 and guide ring 92 will become greater than the distance B between the upper side of rotor 22 and guide ring 92. Guide ring 92 will then be eccentric with respect to rotor 22, causing reciprocation of pump pistons 82*a*

within radial bores 80*a*. If it be assumed that rotor 22 is being driven in the direction of arrow E (see FIG. 3), pistons 82*a* will begin to draw away from shaft 24 as they pass end C of rotor center line C–D. This will cause fluid to be drawn into bore 80*a* from tank 44 through conduit 45, port 212, conduit 210, valve port 208, the leak-by provided on head 192 of valve spool 182, valve recess 204, valve port 160, conduit 126, and port 142. When a pump bore passes end D of center line C–D, the pump piston 82*a* will begin to return toward shaft 24 compressing the fluid within the bore and forcing it under pressure out port 140, conduit 124, valve port 156, valve recess 200, through valve passage 238 to the left end of valve chamber 184. This will cause a pressure buildup on the left end of spool 182 causing it to be shifted to the right as shown in FIG. 10. In this position, spring 250 will be compressed, and spring 248 will be extended; valve block 244 will abut against shoulder 240 and be spaced from the end of valve head 186; valve block 246 will have been moved from shoulder 242 and into abutment with the end of sleeve 258. As a consequence of this rightward movement, valve port 220 will now be in communication with valve recess 200. Thus, hydraulic fluid under pressure will now flow from valve recess 200 through valve port 220 through line 38*a* to hydraulic work unit 36*a*, from which it will return via line 40*a* to valve port 226. Should the pressure in valve recess 200 be excessive, pop valve 224 will open permitting fluid to flow through conduit 232 (see FIG. 4) to valve recess 202. As fluid returns from the hydraulic work unit through valve port 226, it is received in valve recess 202 and flows through valve port 214 to conduit 216, from which it flows out port 218 through line 41 to condenser 42. After the hydraulic fluid is cooled in condenser 42, it is returned to tank 44 through line 45.

It is to be noted, that the magnitude of fluid flow is regulated by the length of the stroke of the pistons 82*a* of radial pump unit 26*a*. The magnitude of flow is a function of the degree of eccentricity of guide ring 92 with respect to rotor 22 as indicated by the relative magnitudes of distances A and B. The flow can be controlled from as little as a few drops per minute for precise control of a cylinder in hydraulic work unit 36*a* up to the full flow permitted by the speed of rotation of rotor 22 and the capacity of the cylinders of the radial pump unit.

Should it be desired to reverse the direction of flow through hydraulic work unit 36*a*, it is merely necessary to adjust control assembly 28*a* to reverse the relative size of distances A and B so that guide ring 92 is relatively closer to the underside of rotor 22 than to the upper side. In this case, as the radial bores 80*a* of rotor 22 pass point D of center line C–D, pistons 82*a* will draw away from shaft 24 drawing hydraulic fluid into bore 80*a* from tank 44 through line 45, port 212, conduit 210, port 206, the leak-by permitted by head 186, valve recess 200, valve port 156, conduit 124, and port 140. When the radial bores pass point C of centerline C–D, the pistons 82*a* return toward shaft 24 compressing the hydraulic fluid and forcing it under pressure out port 142, conduit 126, valve port 160, valve recess 204, and valve passage 236 to the right-hand end of valve chamber 184. This will cause fluid under pressure to act upon the right-hand end of valve spool 182 causing it to move leftward until it attains the position shown in FIG. 12. In this position, spring 248 will be compressed, and spring 250 will be extended. Valve block 244 will abut against the end of sleeve 256, and valve block 246 will abut against shoulder 242. The fluid under pressure in valve recess 204 will be caused to flow out valve port 226, which will now be open, through line 40*a* to hydraulic work unit 36*a* and back from hydraulic work unit 36*a* through line 30*a* to valve port 220. Should the pressure in valve recess 204 be excessive, pop valve 230 will open and cause the fluid to bypass through conduit 232 (see FIG. 4) to valve recess 202. As fluid is received through valve port 220, it will enter valve recess 202 and be returned through valve port 214, conduit 216, port 218, and line 41 to condenser 42 where it will be cooled before being returned through line 43 to tank 44. As with the other direction of fluid flow through hydraulic work unit 36*a*, the magnitude of flow will be a function of the relative magnitude of distances A and B and may vary from a few drops per minute to the full flow permitted by the design of the pump.

As will be noted from the foregoing, it is not necessary to reverse the direction of rotation of rotor 22 in order to reverse the direction of flow through a hydraulic work unit. All that is necessary is suitable adjustment of the control assembly to adjust the eccentricity of guide ring 92 with respect to rotor 22 as already described. In point of fact, various pump units of the system may operate oppositely so that some of the work units operate in one direction, while others of the work units operate in the opposite direction. Moreover, the flow to some work units may be large, while the flow through other work units may be relatively much smaller. A single prime mover rotating in a single direction can thus drive a number of pump units from a single common shaft. Each of the pump units will be individually controlled and independent of the other pump units. The direction of flow from one pump unit through a hydraulic work unit may be opposite to the direction of flow from an adjacent pump unit through another hydraulic work unit with the common shaft driving both pump units still rotating in one direction.

This independent precise flow control and output directional control is a distinct advantage in systems where several motions are desired simultaneously. For example, if a forklift truck were equipped with a hydraulic control system of the present invention, a load, such as an aircraft engine, could be precisely positioned. The forklift truck could be used for positioning the aircraft engine for assembly or disassembly from an aircraft. The truck could have separate hydraulic work units, each coupled to a separate pump unit of the invention, and these hydraulic work units could apply up, down, right, left, tilt-up, tilt-down, or rotational motion to the engine for precise alignment of holes or studs without jogging and with smooth movement because of the close control of flow (from a few drops per minute to the full capacity of the pump units). A forklift truck provided with a hydraulic control system of the present invention could thus readily adjust for lack of surface smoothness and for differing attitudes of the aircraft. In addition, individual hydraulic work units could be added to each wheel of the truck to provide a four-wheel drive.

In general, hydraulic control systems of the invention are extremely versatile and can be used where rugged precise hydraulic systems are employed or required. For example, there will be considerable utility in tanks, gun turrets, and snow removal equipment. On the other hand, hydraulic control systems of the invention can be incorporated in extremely delicate and precise instruments or jigs such as are used in radioactive hot cells for positioning specimens for machining, microscopic studies, and the like. Such fixtures could be remotely controlled from outside the hot cell by either mechanical or electric control systems for positioning the control assemblies of the invention.

Although the present invention has been illustrated by an embodiment having four radial pump units, it is to be understood that any number of radial pump units might be employed on a single shaft within the purview of the present invention. Of course, when the number of radial pump units is increased, it will be necessary to increase the capacity of the prime mover, tank, and condenser so that sufficient fluid will be provided under adequate pressures.

While a preferred embodiment of the invention has been shown and described, it will be readily apparent to those skilled in the art that changes can be made without departing from the principles and spirit of the invention, the scope of which is defined in the appended claims. Accordingly, the foregoing embodiment is to be considered illustrative rather than restrictive of the invention, and those modifications which come within the meaning and range of equivalency of the claims are to be included therein.

The invention claimed is:

1. A hydraulic control system comprising: drive means; rotor means driven by said drive means and including a plurality of radial pump units, each pump unit having a plurality of radial bores and a piston in each bore; conduit means for conducting fluid to and from said pump units; and individual control means for each radial pump unit for adjusting the radial stroke of the pistons of each unit, whereby the direction and magnitude of fluid flow in said conduit means from each of said pump units is controlled independently of the direction and magnitude of flow in the remaining pump units and the direction of rotation of said rotor means, said system further comprising a stationary shaft about which said rotor means rotates, said conduit means including a first conduit within said shaft communicating with a first port extending about a first substantial portion of the circumferential portion of the circumference of said shaft and adapted to receive fluid from or supply fluid to said radial bores as said bores pass thereover and a second conduit within said shaft communicating with a second port extending about a second substantial portion of the circumference of said shaft and adapted to receive fluid from or supply fluid to said radial bores as said bores pass thereover, and wherein said conduit means comprises valve means for controlling the direction of fluid flow in a pair of fluid lines to and from a hydraulic work unit in response to the direction of fluid flow in said first and second conduit.

2. A hydraulic control system as recited in claim 1, wherein said valve means comprises a valve body having a plurality of valve chambers within a valve casing, spring means for biasing said valve body to a midposition, within said casing, and means communicating fluid under pressure from one of said ports to a corresponding end of said valve body to shift said valve body toward the other end thereof and establish a fluid path from said one of said ports to a corresponding one of said fluid lines.

3. A hydraulic control system as recited in claim 2, wherein said valve means, when shifted toward said other end, also establishes a fluid path to a condenser from said other fluid line.

4. A hydraulic control system as recited in claim 2, wherein said valve body includes four valve heads defining three valve chambers, two of said valve heads closing said fluid lines when said valve body is biased to said midposition, and said fluid lines communicating with two of said chambers when said valve body is shifted toward either end.

5. A hydraulic control system as recited in claim 4, wherein said valve further comprises a block at each end of said valve casing and said spring means comprises a spring at each end of the valve casing bearing against a corresponding one of said blocks.