

[54] **HYDRAULIC SYSTEM FOR  
INDIVIDUALLY CONTROLLING A  
PLURALITY OF HYDRAULIC MOTORS**

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91/414, 239/177

[51] Int. Cl. .... **F15b 11/16**

[58] Field of Search ..... 91/414, 411 R; 60/53 R

[56] **References Cited**

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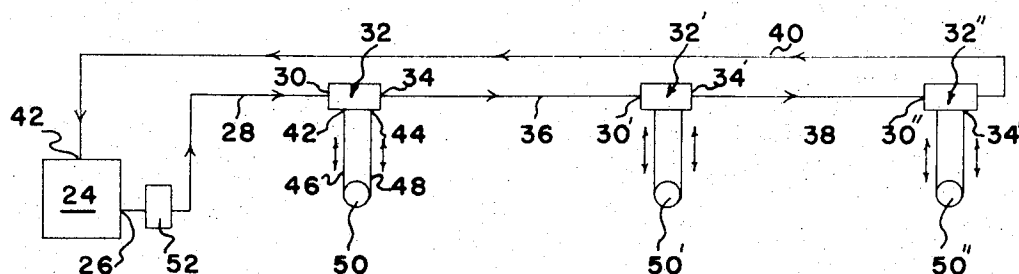
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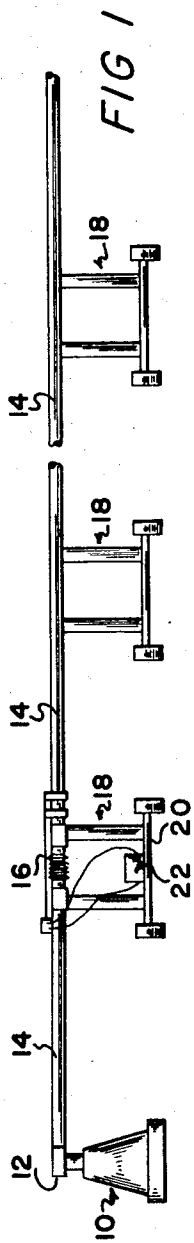
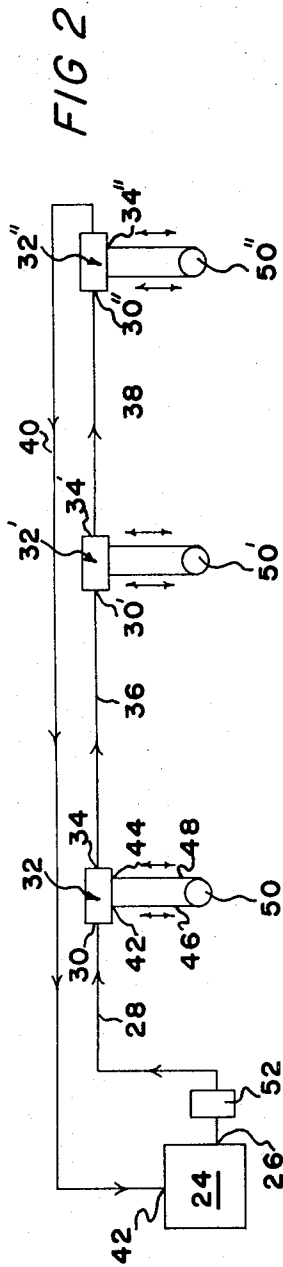
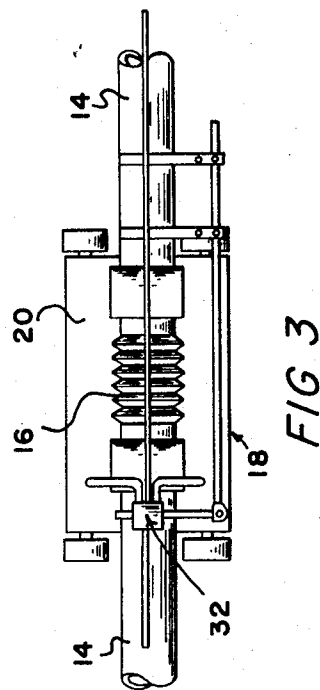
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[57] **ABSTRACT**

A hydraulic system for independently controlling a plurality of individual reversible variable speed hydraulic motors from a common pressure supply source. A plurality of control valves, one for each motor to be controlled, are connected in a closed series circuit with a pump which is operable to recirculate fluid under pressure through the circuit. Each valve, when located in a centered or neutral position, permits all fluid entering the valve inlet to pass directly to the valve outlet. Upon displacement from the neutral position, a portion of the flow into the valve inlet is diverted to the associated motor, passes through the motor and is returned to the valve to rejoin the nondiverted portion of the flow. The magnitude and direction of flow through the motor is dependent upon the magnitude and direction of displacement of the valve from its neutral position. Displacement of a valve in either direction beyond a selected maximum displacement blocks the inlet port of the valve and the resultant increase of pressure at the pump triggers a pressure responsive switch to shut down the pump.

**3 Claims, 8 Drawing Figures**





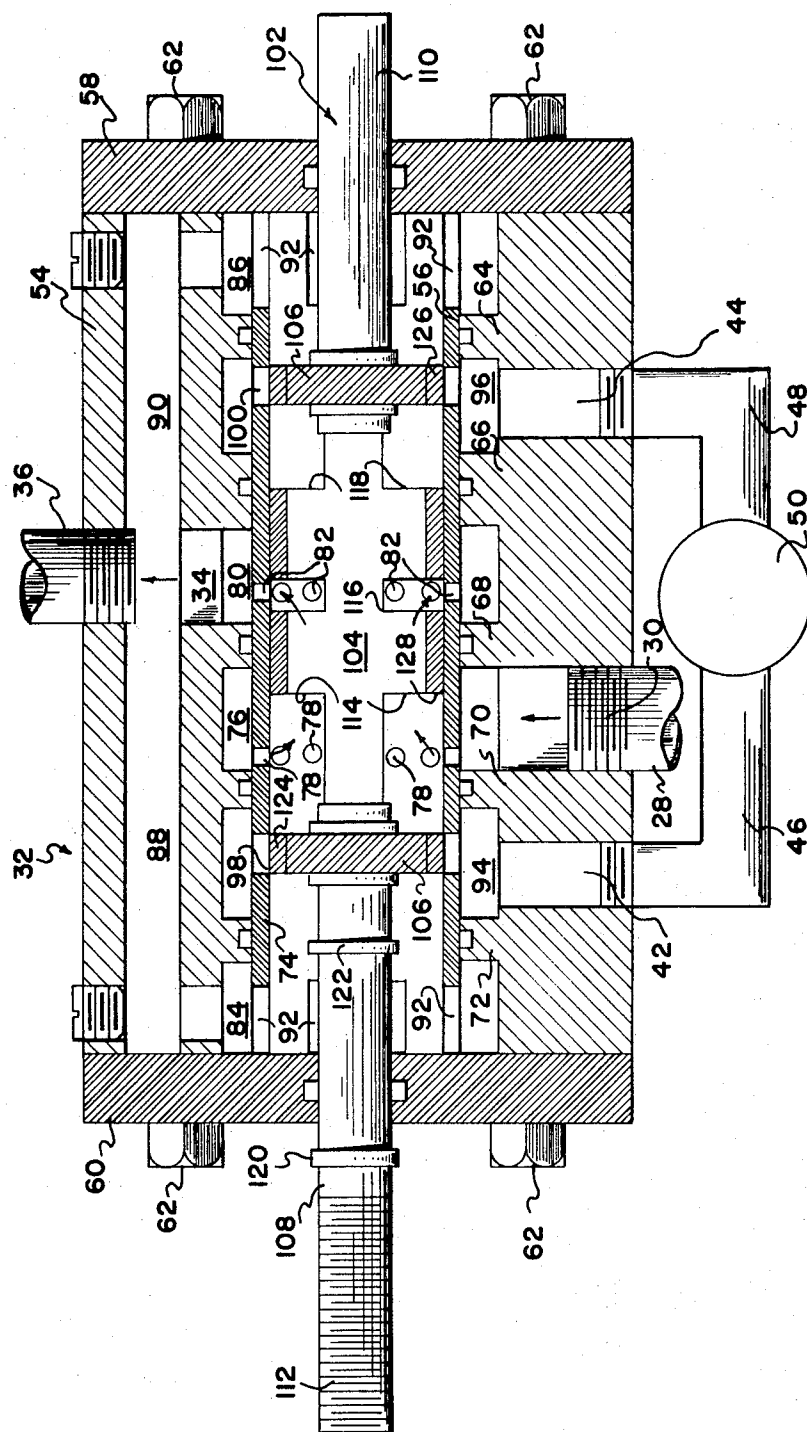


FIG 4

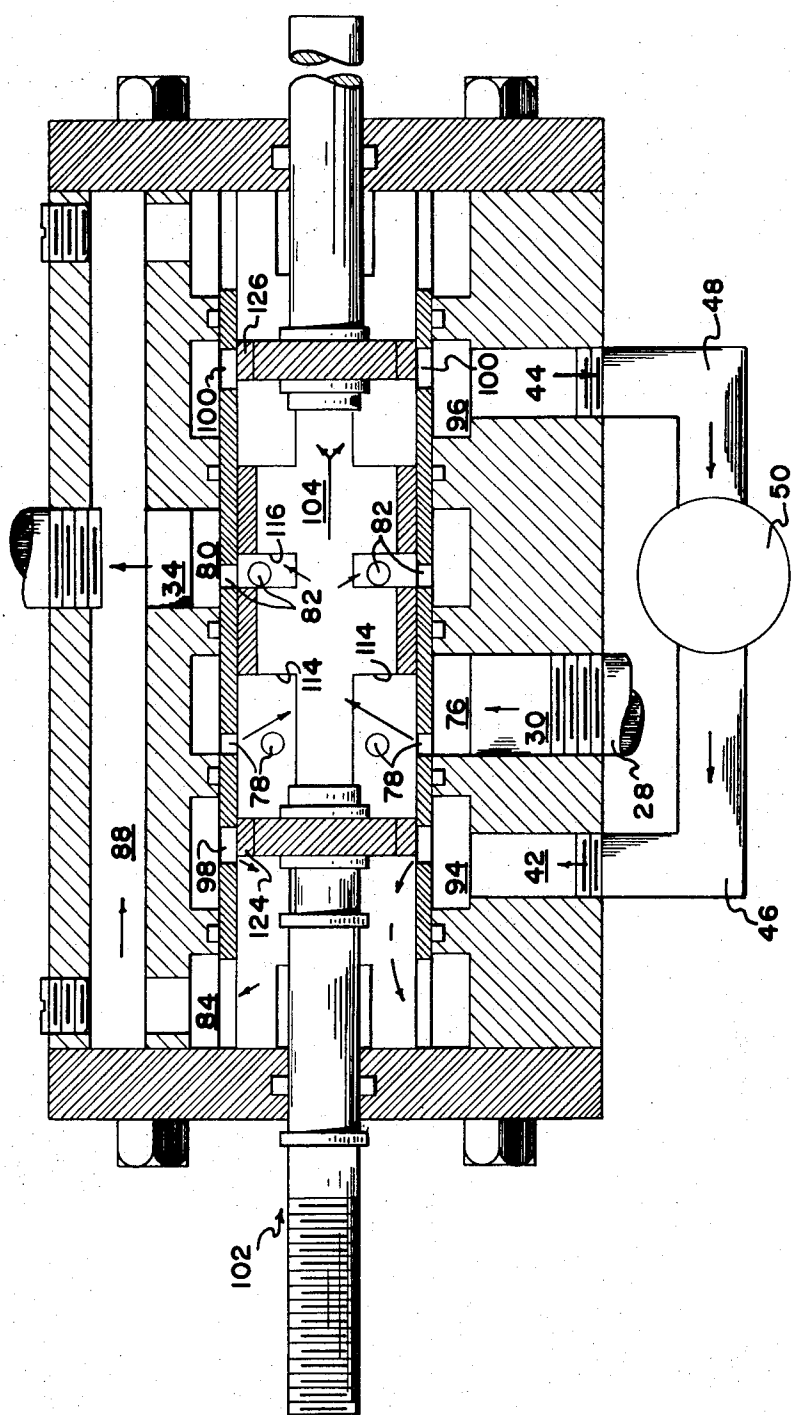
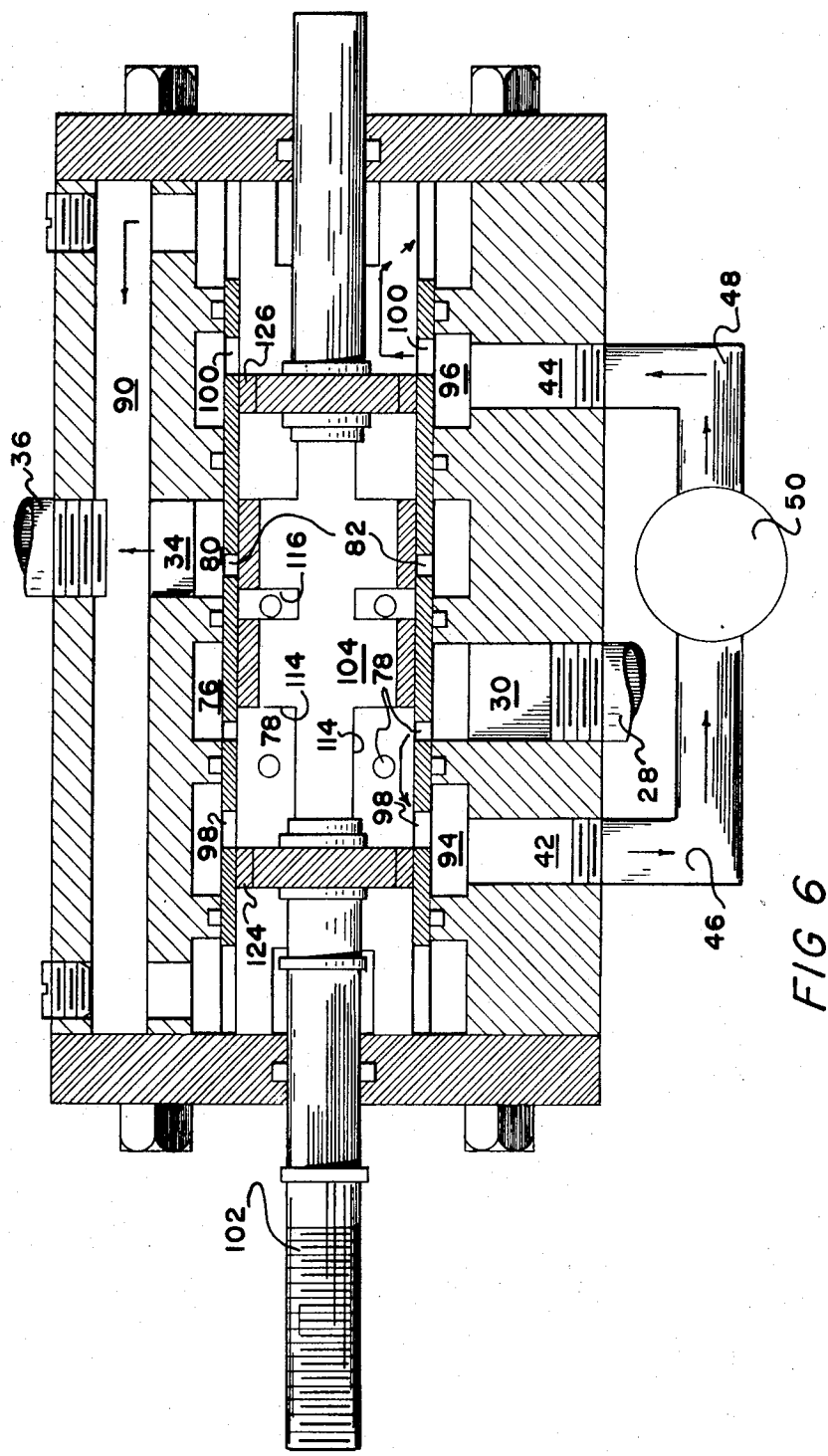
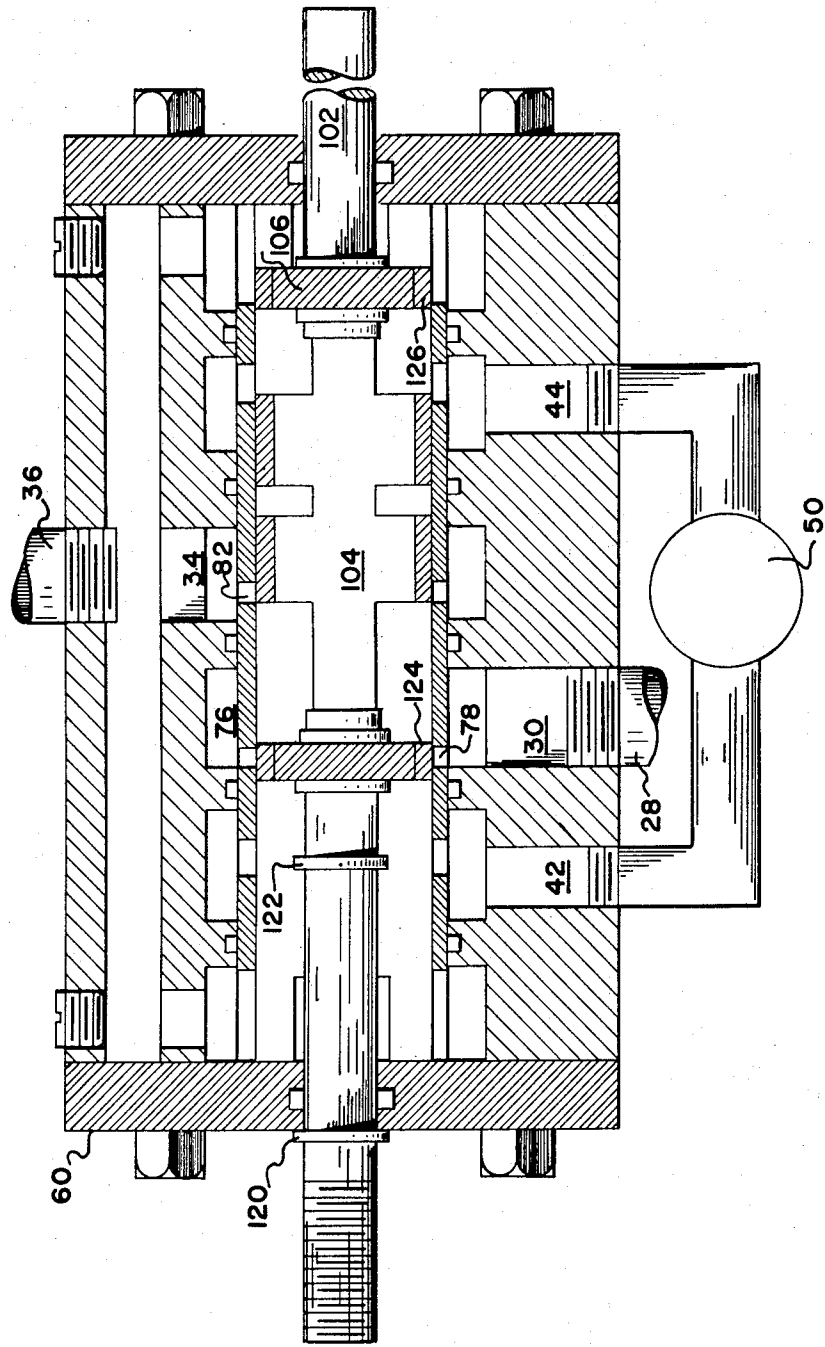


FIG 5





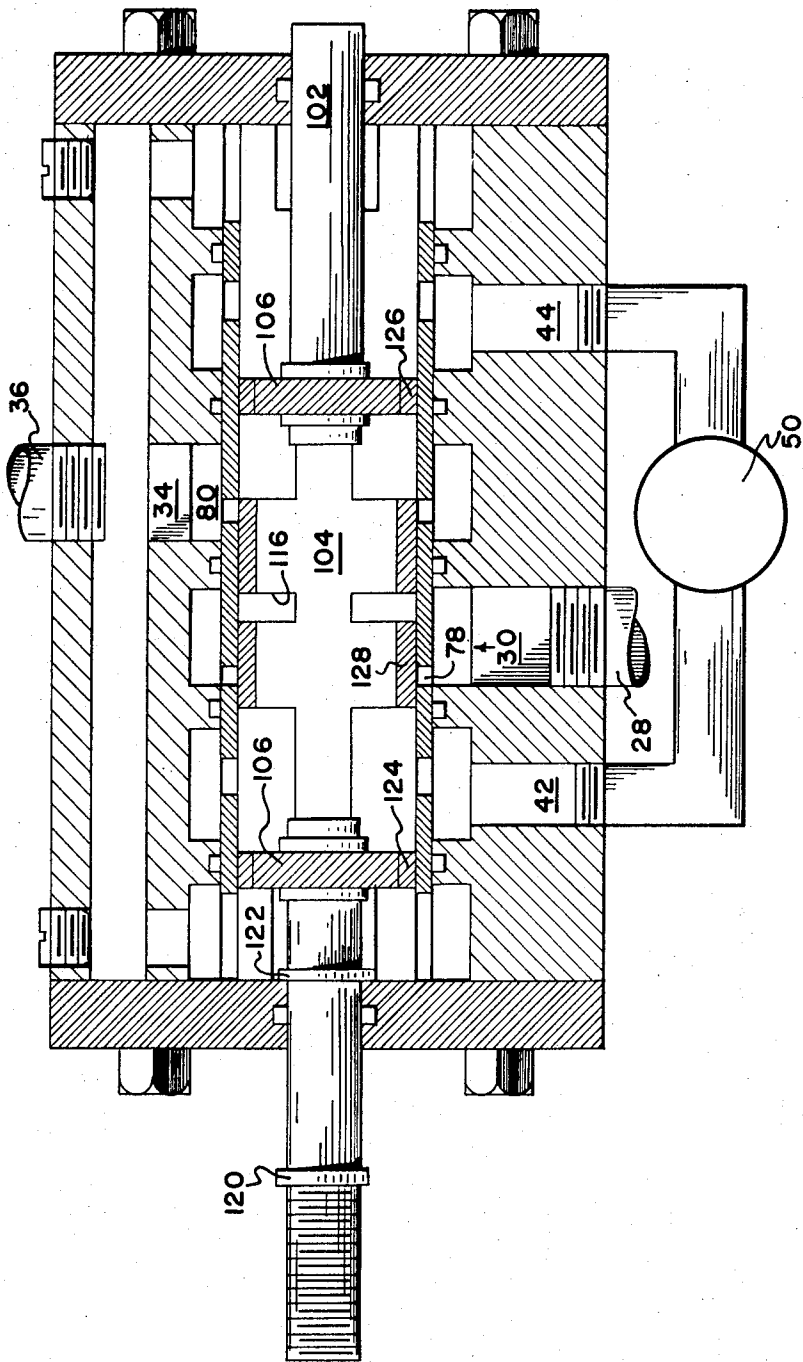


FIG 8

# HYDRAULIC SYSTEM FOR INDIVIDUALLY CONTROLLING A PLURALITY OF HYDRAULIC MOTORS

## REFERENCE TO RELATED APPLICATION

This application is a division of my copending application Ser. No. 66,360 filed Aug. 24, 1970 now U.S. Pat. No. 3,643,700, granted Feb. 22, 1972.

## BACKGROUND OF THE INVENTION

Although it has applicability in many other environments, the system of the present invention was designed for use in self propelled irrigation systems of the type wherein a radially extending string of water distribution pipe is driven in movement about a central point to irrigate a circular area of land. Sprinkler systems of this type are commonly employed in the more arid regions of the great plains. The pipe strings are of substantial length in many instances, normally several hundred feet or more, and are supported and driven by towers or carriages located at spaced points along the string. Each tower is provided with an individual drive motor, and the problem is to coordinate the control of the various individual motors so that the entire string is maintained in accurate radial alignment from the central pivot point. This is an exceedingly difficult task, complicated by the fact that at any given moment some towers may be going up hill or passing through a muddy section while other towers are on a downgrade or passing over firmly compacted soil.

In most systems of this type, two sections of the pipe string are joined to each other at a tower by a flexible coupling which accommodates pivoting movement of the two sections relative to each other. Typically, a valve housing mounted on one of the two sections near the joint is actuated by a control element or linkage based on the other of the two sections so that relative pivotal movements of the two sections will shift the valve actuator.

Many of the presently used systems of this type employ the sprinkler system water as the fluid pressure source. In practice, this has usually turned out to be unsatisfactory for several reasons such as variation in pressure or lack of sufficient pressure. Further, many systems which employ water pressure as the power source are known as open circuit systems, i.e. water used for motive power of the tower is discharged directly on the ground from the driving mechanism.

## SUMMARY OF THE INVENTION

The present system employs a closed hydraulic system in which a high pressure pump and a plurality of control valves are connected in a closed series circuit. Each valve is connected by a pair of control conduits to a reversible variable speed hydraulic motor which functions as the power drive unit. Each valve has a spool which is constructed, when in a neutral or centered position, to block both of the control conduits. The valve sleeve also has a pair of ports which provide direct communication between the valve inlet and valve outlet when the valve is in its centered position, at which time all fluid entering the valve inlet passes directly to the valve outlet. The valve housing is mounted upon one pipe section adjacent a joint; a lever mounted on the adjacent pipe section is employed to

position the valve actuator in accordance with the angular position of the two pipe sections relative to each other. Displacement of the valve spool from its neutral or centered position partially closes the sleeve port at the valve outlet, and at the same time, connects one of the control ports to the inlet port while simultaneously connecting the other control port to the valve outlet, thus diverting a portion of the incoming fluid flow to pass through the hydraulic motor, from which it is returned to the valve and passed to the valve outlet. The magnitude and direction of the flow through the motor is dependent upon the magnitude and direction of displacement of the valve spool from its neutral position. The capacity of the pump is selected to be relatively high as compared to the operating characteristics of the individual power drive motors. Preferably, the motors will operate at full speed in either direction with a pressure drop of the order of 50 psi across the motor, the pump operating pressure being approximately 1250 psi.

A safety shut off feature is provided to protect against jack-knifing or breaking of the pipe string by shutting off the pump in the event a selected maximum angular displacement between two adjacent pipe sections is reached. This situation normally arises when one tower becomes bogged down or loses its traction. The safety shut down is achieved by constructing the valve spool in a manner such that when the valve spool is displaced by a given maximum distance from its center position, the valve inlet port becomes blocked, thus increasing the pressure at the pump outlet port. A pressure responsive switch responds to this increase in pressure to shut down the pump drive, thus stopping all movement of the string.

Other objects, features and advantages of the invention will become apparent by reference to the following specification and to the drawings.

## IN THE DRAWINGS

FIG. 1 is a side elevational view of a typical self propelled irrigation system;

FIG. 2 is a schematic diagram of a hydraulic system embodying the present invention;

FIG. 3 is a schematic top plan view of a tower and section joint of the system of FIG. 1;

FIG. 4 is a cross-sectional view of a valve employed in the hydraulic system of FIG. 2 showing the valve in its neutral or centered position;

FIG. 5 is a cross-sectional view of the valve of FIG. 4, showing the valve spool displaced by a slight amount in one direction from its neutral position;

FIG. 6 is a cross-sectional view of the valve of FIG. 4 showing the valve displaced in the opposite direction, and by a greater amount, as compared to FIG. 5;

FIG. 7 is a cross-sectional view of the valve showing the valve spool and maximum displacement in one direction; and

FIG. 8 is a cross-sectional view of the valve showing the valve spool at maximum displacement in the opposite direction from FIG. 7.

Referring first to FIG. 1, there is shown in side elevational view, in more or less diagrammatic form, a self propelled irrigation system of the type discussed above. Systems of this type are well known — see for example, Patent Office class 239, subclass 177. Typically, such

systems include a central frame assembly designated generally 10, usually constructed at the well head of an artesian well or some other source of water, not shown. A rotating union 12 is employed to conduct water from the well or other source to a distribution system made up of a series of pipe section 14 interconnected in series with each other by flexible joints or couplings 16. Pipe sections 14 extend radially from the rotary union 12, water being pumped through the connected pipe sections and disburse from the pipe by any of several forms of sprinkler means, not shown, suitably located along the pipe string. At spaced intervals along the pipe string, towers designated generally 18 support adjacent ends of adjacent pipe sections 14.

Each tower includes a suitable supporting frame work which is mounted upon a wheeled carriage 20, each carriage 20 having a drive means designated generally 22. The drive means are operated to drive the various towers along circular paths about the central pivot constituted by frame 10 while water is sprinkled from the distribution system which includes pipe sections 14, to irrigate the circular area traversed by the pipe string. The pipe string made up of pipe sections 14 typically is several hundred feet in length, and it is thus apparent that the circular path traversed by the outermost tower 18 may be many times longer than that traversed by one of the inner towers 18. Thus, each tower, in order to keep the string of pipes 14 in a straight line relationship to each other, must be driven at a speed dependent upon the radial distance between the tower and central frame 10, and the speed must be accurately regulated so that precise alignment of all of the towers 18 radially from central frame 10 is maintained. Further, because of a substantial length of the pipe string, the terrain being traversed at any given time can vary widely from tower to tower, and hence it is necessary to continually adjust and readjust the speed of the individual tower motors.

A hydraulic system for independently controlling the speed of a number of individual reversible variable speed hydraulic motors supplied with pressure fluid from a common pressure source is shown in FIG. 2. The system includes a supply pump schematically illustrated at 24 whose high pressure side or outlet is connected via a conduit 28 to the inlet port 30 of a control valve 32. The outlet port 34 of valve 32 is connected via conduit 36 to the inlet port 30' of a second similar valve 32', whose outlet port 34' is connected via a conduit 38 to the inlet port 30'' of a third similar control valve 32''. The outlet port 34'' of valve 32'' is connected via a conduit 40 to the intake port 41 of the pump 24. The pump 24 is thus operable to continuously recirculate fluid under pressure through the series connected valves 32, 32' and 32'' and thence back to the pump intake via conduit 40. For purposes of illustration, the circuit of FIG. 2 is shown with only three control valves, however, in practice the number of valves in the circuit will correspond to the number of individual motors to be controlled — in the case of the irrigation system of FIG. 1, each tower 18 will be supplied with a valve 32.

Valve 32 is constructed with a pair of control ports 42, 44 which are respectively connected via conduits 46 and 48 to the opposite sides of a reversible variable speed hydraulic motor 50 which, in the irrigation

system of FIG. 1 would constitute the drive motor of drive means 22. Motors 50 are of well-known, conventional construction and operate to drive in either direction at a speed dependent upon the rate of flow of hydraulic fluid through the motor, the direction of drive being determined by the direction in which the fluid flows through the motor. Valves 32' and 32'' are similarly connected to corresponding motors 50' and 50''.

The structure and operation of valve 32 is best seen in FIGS. 4 through 8 inclusive. Valve 32 is constructed with a main housing 54 having a central bore or chamber 56 which extends longitudinally entirely through housing 54. End caps 58 and 60 close the opposite ends of bore 56 and are sealingly secured to the opposite ends of housing 54 as by bolts 62. A series of annular lands 64, 66, 68, 70 and 72 in bore 56 cooperate with a fixed tubular sleeve 74 to form a series of internal chambers within the housing at the exterior of sleeve 74. Inlet port 30 takes the form of a bore passing through housing 54 to communicate with an inlet chamber 76 located at the exterior of sleeve 74 between lands 68 and 70. Inlet chamber 76 can communicate with the interior of sleeve 74 via a plurality of ports 78 through sleeve 74. Outlet port 34 of valve 32 likewise takes the form of a bore passing through housing 54 to communicate with an outlet chamber 80 located at the exterior of sleeve 74 between lands 68 and 66. Again, a series of radial ports 82 through sleeve 74 place outlet chamber 80 in communication with the interior of sleeve 74. Outlet port 34 is also in constant communication with end chambers 84 and 86 located at the opposite ends of bore 56 via branch passages 88 and 90 respectively. Chambers 84 and 86 are in constant communication with the interior of sleeve 74 via slots 92 extending axially inwardly from the opposite ends of sleeve 74. Control ports 42 and 44 pass inwardly through housing 54 to communicate respectively with chambers 94 and 96. Ports 98 and 100 respectively pass through the wall of sleeve 74 to provide a communicating passage between chambers 94 and 96 and the interior of sleeve 74 when ports 98 and 100 are unblocked.

A valve actuator designated generally 102 is slidably received within fixed sleeve 74. Actuator 102 includes a central hollow tubular sleeve portion 104 having closure plugs 106 sealingly secured in each of its opposite ends. Guide stems 108 and 110 are fixedly secured to and project from plugs 106, guide stem 110 being slidably and sealingly mounted in end cap 58, with guide stem 108 being slidably and sealingly received within end cap 60. The projecting portion of stem 108 is formed with a threaded section 112 so that the stem may be connected to a valve actuator to axially shift valve member 102 within fixed sleeve 74.

Central sleeve portion 104 of member 102 is formed, near its left hand end as viewed in FIG. 4, with a series of axially elongated slots 114 which are normally aligned with, and thus uncover ports 78. Relatively narrow slots 116 are formed near the central portion of sleeve 104 to be located in alignment with ports 82 in sleeve 74 when valve 102 is at or closely adjacent its neutral or centered position shown in FIG. 4. The axial width of slots 116 slightly exceeds the diameter of ports 82. A third series of slots 118 is formed adjacent the right hand end of sleeve 104.

Axial movement of member 102 relative to valve housing 54 is limited by a pair of spaced stop elements 120, 122 mounted on guide stem 108 to engage end cap 60 upon a selected axial displacement of the valve member 102 from the neutral or central position shown in FIG. 4.

When valve member 102 is in its centered or neutral position shown in FIG. 4, ports 98 in fixed sleeve 74 are blocked by the end portion 124 of central sleeve 104, while ports 100 are likewise blocked by the opposite end portion 126 of central sleeve 104. When in this position, fluid under pressure entering in the inlet port 30 passes from chamber 76 radially inwardly through ports 78 and slots 114 to the interior of central sleeve 104 and thence radially outwardly through ports 82, outlet chamber 80 and outlet port 34. All of the fluid entering inlet port 30 follows the foregoing path, end portions 124 and 126 of the central sleeve blocking communication between the sleeve interior and either of control chambers 94 and 96. It will be noted that in this condition, the valve is hydraulically balanced, equal and oppositely directed pressures being exerted against the inner walls of end plugs 106 and likewise against the respective outer walls of plugs 106 which are maintained at the pressure existing at outlet port 34 via branch passages 88, 90, and the outer end chambers via chambers 84 and 86. When the valve is in its centered position, no fluid flow exists to or from either of control ports 42 or 44 and hence motor 50 is inoperative.

In FIG. 5, a valve actuator 102 is shown displaced by a small amount to the right from its center or neutral position. As in the previous case, fluid entering inlet port 30 is passed from inlet chamber 76 inwardly through ports 78 and slots 114 of central sleeve 104 to the interior of the sleeve. Although slot 116 of sleeve 104 has been displaced slightly to the right, outlet ports 82 are still uncovered by slot 116 to permit fluid to flow from the interior of sleeve 104 through slot 116, ports 80 and chamber 82 and to outlet port 34.

The slight rightward displacement of valve member 102 has shifted right hand end portion 126 of inner sleeve 104 to the right to partially uncover ports 100, thus permitting a small amount of fluid to flow from inlet port 30 and the interior of sleeve 104 through ports 100 into control chamber 96 and thence through control port 44, conduit 40 and conduit 48 to motor 50.

The slight rightward displacement of valve member 102 also is caused in portion 124 of sleeve 104 to partially unblock ports 98 to place control chamber 94 in communication with the left hand end chamber of bore 56 and thus with chamber 84, branch passage 88 and outlet port 34. These latter connections permit fluid to flow from motor 50 via conduit 46, control port 42 to outlet port 34, thereby establishing an operating flow of fluid through motor 50 to cause motor 50 to drive in one direction at a speed proportional to the magnitude of fluid flow through the motor.

In FIG. 6, the valve is shown displaced to the left from its neutral position by a greater amount than the slight displacement of FIG. 5. In FIG. 6, valve member 102 has been shifted to the left by an amount such that slot 116 in valve sleeve 104 has been moved completely out of alignment with ports 82 in fixed sleeve 74, thereby blocking all direct communication between

inlet port 30 and outlet port 34. The respective end portions 124 and 126 of sleeve 104 have been displaced from their centered position by a distance sufficient to completely uncover both of ports 98 and 100, ports 98 now being completely and directly connected to inlet port 30 via ports 78 and slots 114. Thus, all of the fluid flowing into inlet port 30 passes through ports 98 into control chamber 94, and thus via control port 42 and conduit 46 to motor 50. Fluid passing from motor 50 travels via conduit 48 to outlet port 44 and chamber 96, thence via the now completely open ports 100 into the right hand end chamber of bore 56 and thence via branch conduit 90 to outlet port 34. In this condition of the valve, motor 50 is receiving the full flow from inlet port 30 and thus will be driving at maximum speed in the direction opposite to that in which it was driven by rightward displacement of the valve in FIG. 5.

From a comparison of FIGS. 4, 5, and 6 it is seen that movement of valve member 102 in either direction from its center or neutral position causes the end sections 124 and 126 of sleeve 104 to gradually uncover ports 98 and 100 to place the ports in communication with inlet port 30 or with the adjacent end chamber of bore 56, dependent upon the direction of displacement of member 102. The degree of communication is directly dependent upon the amount of displacement of member 102 and a corresponding throttling of ports 82 occurs. This arrangement provides for an establishment of a flow of fluid through the connected motor 50 in a direction and magnitude directly related to the direction and magnitude of displacement of member 102 from its neutral position.

Valve 32 is provided with a safety shutoff feature to cause a shut down of the system in the event the displacement of valve member 102 exceeds a selected maximum displacement in either direction from its centered or neutral position. Displacement of valve member 102 from its centered or neutral position will normally represent an error signal which will, upon displacement of the valve, cause motor 50 to drive in a direction tending to correct the error. In many instances, the application of an abnormally large error signal indicates the existence of an abnormal fault, malfunction or emergency. In the irrigation system described above, for example, a typical situation of this type is encountered when the driving wheels of one of the towers become bogged down or completely lose traction so that the tower is unable to move, regardless of the amount of power applied to its drive motor. Adjacent towers, at this time, may have full traction and continue to drive ahead, thus continuously increasing the angular misalignment at the joint on the stalled tower and driving the pipe string into a jackknifed condition. When this occurs, it is obviously desirable to immediately stop all of the power drive motors to prevent jackknifing of the pipe string.

In the disclosed valve, the axial length of slots 114 in sleeve 104 determine the amount of displacement of valve member 102 which can occur before shutdown of the system will take place. It will be noted from FIG. 4 that ports 78 which communicate with inlet port 30 are located midway axially of slots 114. If valve member 102 is displaced in either direction from the FIG. 4 position by a displacement greater than one-half the

length of slots 114, it is believed apparent that ports 78 will be covered either by end section 124 in the case of displacement of member 102 to the right or by edge portion 128 of sleeve 104 upon displacement of member 102 to the left.

These conditions of maximum displacement are shown respectively in FIGS. 7 and 8. Referring to FIG. 7, valve member 102 is shown at its maximum rightward displacement, with stop member 120 seated against the outer side of end cap 60 and end section 124 of sleeve 104 blocking ports 78. With port 78 blocked by end section 124, fluid flowing into inlet port 30 can not proceed beyond inlet chamber 76 and thus continued operation of the pump which supplies fluid to inlet port 30 will cause a build up of pressure. Referring to FIG. 2, in the event that any of the inlet ports 30, 30', or 30'', of FIG. 2 should become blocked, it is believed apparent that pressure will immediately build up in conduit 28 to the full pump output pressure. Pressure responsive switch 52, connected in conduit 28 is set to be triggered by such an increase in pressure and switch 52 is electrically connected to stop operation of pump 24 in the event of an increase in pressure occasioned by blockage of the inlet port 30 of any of the valves in the system.

In FIG. 8, it is seen that displacement of valve member 102 to the left beyond a selected maximum displacement position of section 128 of valve sleeve 104 blocks ports 78 with the same end result as described immediately above.

While one embodiment of the invention has been described in detail, it will be apparent to those skilled in the art that the disclosed embodiment may be modified. Therefore, the foregoing description is to be considered exemplary rather than limiting, and the true scope of the invention is that defined in the following claims.

I claim:

1. A hydraulic system for independently controlling a plurality of reversible variable speed hydraulic motors comprising a plurality of like control valves each having a pair of control ports connected to one of said motors, an inlet port, and an outlet port, pump means having an intake port and an outlet port and operable to

discharge fluid under pressure from said output port, conduit means connecting said pump means and control valves in a closed series circuit via said inlet and outlet ports with the first valve in said series having its inlet port connected to the pump output port and the last valve in said series having its outlet port connected to the pump intake port, each of said valves having a valve member movable in either direction from a neutral position, first means in said valve member for conducting all fluid entering the valve inlet port to the valve outlet port when said valve member is in said neutral position, and second means on said valve member operable upon displacement of said valve member from said neutral position to divert a portion of the fluid entering the valve inlet port from said outlet port to one of said control ports and to connect the other of said control ports to the valve outlet to establish a flow of diverted fluid from said inlet port through the associated motor to said outlet, the magnitude and direction of said diverted flow varying in accordance with the magnitude and direction of displacement of said valve member from said neutral position.

2. A system as defined in claim 1 wherein said first means comprises means in said valve member defining an opening in registry with said outlet port when said valve member is in said neutral position, and said second means comprises a pair of annular end elements located to respectively block said control ports when said valve member is in said neutral position whereby upon movement of said valve member away from said neutral position, said outlet port is progressively restricted as said one of said control ports is progressively unblocked.

3. A system as defined in claim 1 further comprising shut down means in said valve member operable upon a predetermined maximum displacement of said valve member in either direction from its neutral position to block the valve inlet port, and pressure responsive control means responsive to the pressure in said conduit means between said pump outlet port and said first valve for stopping operation of said pump means upon the blocking of the inlet port of any of said plurality of valves.

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