

April 4, 1944.

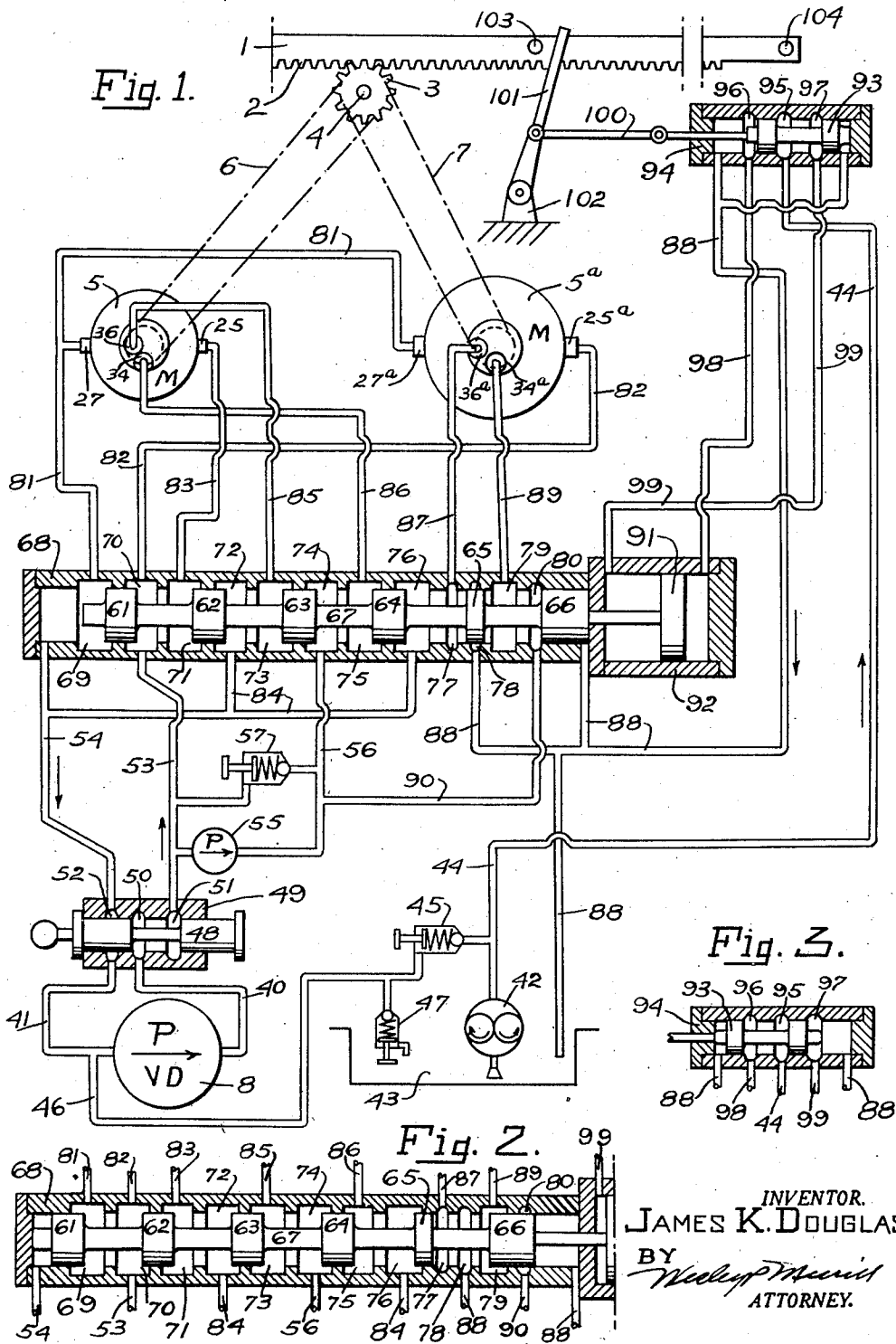
J. K. DOUGLAS

2,345,920

HYDRAULIC DRIVE

Filed Dec. 29, 1939

2 Sheets-Sheet 1



April 4, 1944.

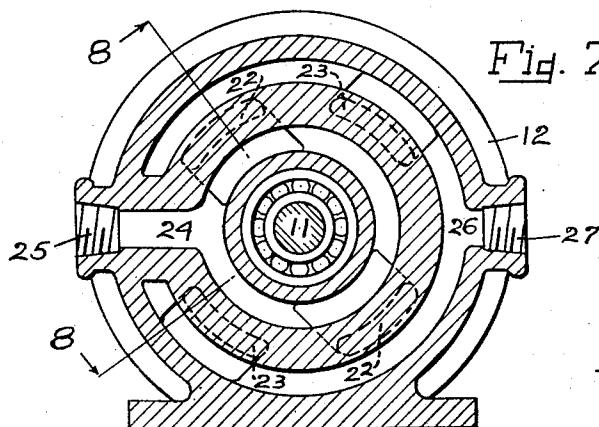
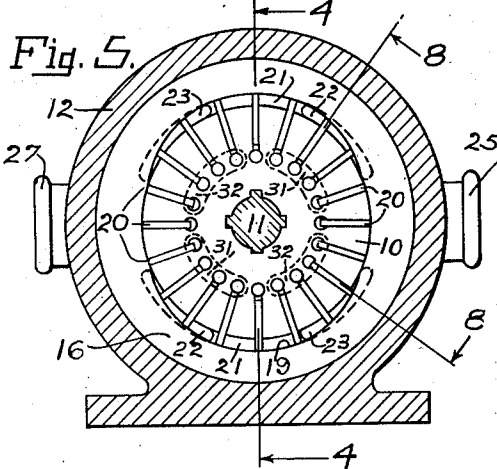
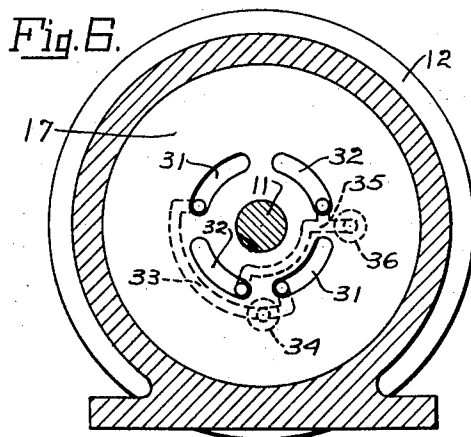
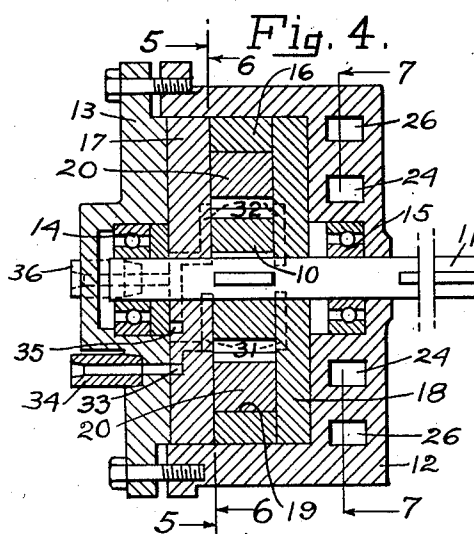
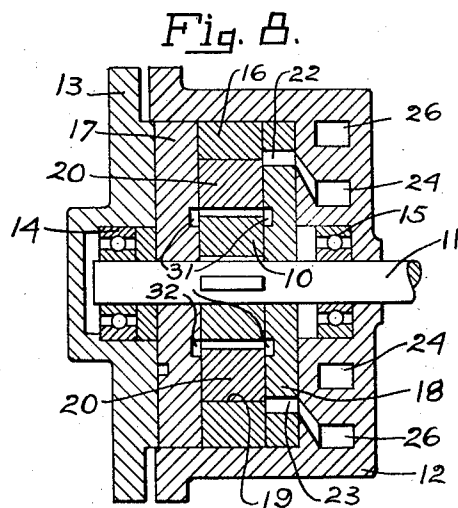
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HYDRAULIC DRIVE

Filed Dec. 29, 1939

2 Sheets-Sheet 2



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2,345,920

HYDRAULIC DRIVE

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Application December 29, 1939, Serial No. 311,479

15 Claims. (Cl. 60—53)

This invention relates to a hydraulic drive of the type which includes the rotary hydraulic motor for driving a machine or an element of a machine, a pump for supplying liquid to the motor to cause it to drive the machine or machine element in one direction, and means for reversing the flow of liquid to thereby cause the motor to drive the machine or machine element in the opposite direction.

The invention has as an object to provide a hydraulic drive which will drive a machine or machine element at one speed in one direction and at a different speed in the opposite direction without varying the displacement of the pump, the displacement of the motor or the speed of the pump.

Another object is to provide a hydraulic drive in which the motor may be caused to rotate in one direction at the maximum speed determined by the capacity of the pump and caused to rotate in the opposite direction at a greater speed.

Another object is to provide such a drive which is fully automatic in operation.

Another object is to provide a drive of the above character which may be manufactured much more economically than the drives ordinarily used for such purpose.

Other objects and advantages will appear from the following description of an embodiment of the invention shown schematically in the accompanying drawings in which the views are as follows:

Fig. 1 is a diagram of the hydraulic circuit of a drive in which the invention is embodied.

Fig. 2 is a view showing a control valve in a position different from that shown in Fig. 1.

Fig. 3 is a view showing a pilot valve in a position different from that shown in Fig. 1.

Fig. 4 is a vertical longitudinal section through one of the motors shown in Fig. 1, the view being taken on the line 4—4 of Fig. 5.

Fig. 5 is a transverse section through the motor taken on the line 5—5 of Fig. 4.

Fig. 6 is a transverse section taken through the motor on the line 6—6 of Fig. 4.

Fig. 7 is a transverse section through the motor taken on the line 7—7 of Fig. 4.

Fig. 8 is a vertical section taken on the irregular lines 8—8 of Figs. 5 and 7.

For the purpose of illustration, the invention has been shown embodied in a drive for a machine of the type having a carriage which makes an idle stroke in one direction at high speed and a working stroke in the opposite direction at a lower speed appropriate for a tool to operate

upon a work piece but it is to be understood that the invention is adapted to various other uses.

The machine includes a carriage 1 having a rack 2 fixed upon the under side thereof and in mesh with a gear 3 which is fixed upon a shaft 4 so that rotation of shaft 4 in one direction or the other will cause carriage 1 to move in one direction or the other. Since the machine per se forms no part of the present invention, all other parts thereof have been omitted from the drawings.

Shaft 4 is adapted to be rotated by two vane type hydraulic motors 5 and 5^a which are connected thereto by suitable drives 6 and 7 respectively. Motors 5 and 5^a are energized by a pump 8 which delivers liquid to both motors to cause them to move carriage 1 in one direction at a cutting speed and then delivers its entire output to motor 5 only to cause it to move carriage 1 at high speed in the opposite direction at which time motor 5^a is short circuited and the vanes thereof are retracted so that its rotor spins idly as presently will be explained.

The two motors may be of the same size but motor 5^a has been shown as being larger than motor 5 in order to obtain a high speed of carriage 1 during its return stroke. For example, if the displacement of motor 5^a is twice that of motor 5, carriage 1 will be moved during its idle stroke at a speed three times its speed during its working stroke.

Motor 5 may be of the type shown in Figs. 4 to 8 and motor 5^a may be exactly the same except that it may be of a different size if desired. As shown, the motor includes a rotor 10 keyed upon a shaft 11 and arranged within a stator consisting primarily of a casing 12 which has a removable end head 13 and rotatably supports shaft 11 by means of bearings 14 and 15, a spacer ring 16 which is arranged within casing 12 and extends around rotor 10, and two cheek plates 17 and 18 which are arranged within casing 12 upon opposite sides of spacer ring 16, the cheek plates and spacer ring being clamped in position by end head 13 and spacer ring 16 being just enough thicker than rotor 10 to permit rotor 10 to turn freely between cheek plates 17 and 18.

The inner peripheral surface of spacer ring 16 provides a track 19 for a plurality of vanes 20 which are the same width as rotor 10 and fitted in slots formed radially therein. Vane track 19 is approximately elliptical with its short diameter horizontal and just enough greater than the diameter of rotor 10 to permit rotor 10 to turn

freely. The vertical diameter of track 19 is enough greater than the diameter of rotor 10 to provide a working chamber 21 of the desired size both above and below rotor 10.

Each chamber 21 communicates with two ports 22 and 23 which are arranged upon opposite sides of the vertical center line of track 19 with the two ports 22 arranged diametrically opposite each other and each port 23 spaced approximately 90° from ports 22. Each portion of track 19 between adjacent ends of adjacent ports forms a sealing arc which is ordinarily concentric with rotor 10. The angular distance between adjacent ends of adjacent ports is at least twice as great as the angular distance between adjacent vanes so that each sealing arc will at all times have at least two vanes in contact therewith.

As best shown in Figs. 7 and 8, ports 22 communicate with an annular passage 24 which is formed in the end wall of casing 12 and communicates with a main port 25 by means of which the motor may be connected to one side of a hydraulic circuit, and ports 23 communicate with a passage 26 which is formed in the end wall of casing 12 outward from passage 24 and communicates with a main port 27 by means of which the motor may be connected to the other side of the hydraulic circuit.

The arrangement is such that, when main port 25 is connected to the discharge outlet of a pump or other source of motive liquid and main port 27 is connected to a return or discharge line so that ports 22 function as inlet ports and ports 23 function as discharge ports, the motive liquid entering through each port 22 will exert a force upon the outer portion of that vane which is adjacent the end of port 22 and in contact with the sealing arc of vane track 19. The force exerted by the liquid upon that vane will cause motor 10 to rotate in a counterclockwise direction in respect to Fig. 5 and the liquid will act upon each succeeding vane as it passes the end of port 22 and comes into contact with the sealing arc so that rotor 10 is caused to rotate continuously as long as motive liquid is supplied to port 25. The liquid ahead of each vane will be discharged into the adjacent port 23 as soon as the preceding vane passes the adjacent end of that port 23. When motive liquid is supplied to port 27, the motor will operate in exactly the same manner but in the opposite direction.

It is essential that the vanes just beyond the ends of the inlet ports be held in contact with vane track 19 as otherwise the liquid could flow freely from each inlet port to a discharge port and no rotative force would be transmitted to rotor 10. These vanes may be held in contact with track 19 by subjecting the inner ends thereof to a pressure higher than the pressure prevailing at the inlet ports but, if the inner ends of the vanes were subjected to this higher pressure during a complete revolution of rotor 10, each vane would exert such an excessive force against track 19 during the time its outer end was exposed to the low or negative pressure of the discharge liquid that undue wear of the vanes or tracks might result.

In order to hold the working vanes against the vane track and at the same time to avoid excessive wear of the vanes or tracks, the vanes have the inner ends thereof subjected to a pressure higher than the pressure of the motive liquid only during the time the outer ends thereof are subjected to the pressure of the motive liquid.

As shown, cheek plates 17 and 18 are each provided with a pair of arcuate pressure grooves 31, which are arranged diametrically opposite each other and spaced radially inward from ports 22, and a pair of arcuate pressure grooves 32 which are arranged diametrically opposite each other and spaced radially inward from ports 23, the pressure grooves being spaced a predetermined distance apart and so located that the inner ends of each vane slot will register with the four grooves successively as rotor 10 rotates.

As shown in Fig. 6, the two grooves 31 in cheek plate 17 are connected to each other by a passage 33, which is formed in cheek plate 17 and communicates with a connector 34 carried by end head 13, and the two grooves 32 in cheek plate 17 are connected to each other by a passage 35 which is formed in cheek plate 17 and communicates with a connector 36 carried by end head 13. The pressure grooves in cheek plate 18 communicate with the corresponding pressure grooves in cheek plate 17 through the inner ends of the vane slots and are provided for the purposes of hydrostatically balancing rotor 10.

As previously explained, motor 5^a is exactly the same as motor 5 except that it is larger. Consequently, the main ports and the connectors of both motors have been indicated in Fig. 1 by the same reference numerals but with the exponent "a" added to the reference numerals applied to motor 5^a.

The liquid for operating motors 5 and 5^a is discharged by pump 8 into a channel 40 and the liquid discharged by motors 5 and 5^a is returned to pump 8 through a channel 41. In order to make up for leakage losses and to supercharge pump 8, additional liquid is supplied to channel 41 by a gear pump 42 which draws liquid from a reservoir 43 and discharges it into a channel 44 through which it supplies liquid to a valve operating mechanism to be presently described.

The liquid discharged by gear pump 42 in excess of the liquid required to operate the valve mechanism is exhausted through resistance valve 45 into one end of a channel 46 the other end of which is connected to channel 41. The liquid discharged by gear pump 42 into channel 46 in excess of the liquid required to supercharge pump 8 is exhausted through a relief valve 47 into reservoir 43. Gear pump 42 is thus enabled to maintain in channel 46 a pressure equal to the resistance of valve 47 and to maintain in channel 44 a pressure equal to the sum of the resistances of valves 45 and 47.

Pump 8 is initially controlled by a start and stop valve 48 which is fitted in the bore of a valve casing 49 having three annular grooves or ports 50, 51 and 52 formed therein. Port 50 communicates with channel 40, port 51 communicates with a channel 53 through which liquid is directed to the motors, and port 52 communicates with channel 41 and with a channel 54 through which liquid is returned from the motors.

The arrangement is such that, when valve 48 is in the position shown in Fig. 1, liquid discharged by pump 8 will flow through channel 40 and valve casing 49 into channel 53 and the liquid returned from the motors through channel 54 will flow through port 52 and channel 41 to pump 8. When valve 48 is shifted to the limit of its movement toward the left, it will block port 51 and open port 52 to port 50 so that pump 8 is bypassed.

Liquid for holding the working vanes 20 of

motors 5 and 5^a against vane tracks 19 is supplied by a small capacity pump 55 which is driven in unison with pump 8 and draws liquid from channel 53 and discharges it into a channel 56. The liquid discharged by pump 55 in excess of the volume required to hold the working vanes outward is exhausted through a low pressure resistance valve 57 back into channel 53 so that the pressure in channel 56 is always a few pounds higher than the pressure created by pump 8.

Motors 5 and 5^a are controlled by a plurality of valves which are simultaneously operable to control the flow of liquid to and from the main ports of the motors and the flow of liquid to and from the pressure grooves of the motors. As shown, six valves or pistons 61, 62, 63, 64, 65 and 66 are fixed upon a plunger 67 and closely fitted in the bore of a control valve casing 68 having twelve annular grooves or ports 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79 and 80 formed therein.

Port 69 is connected by a channel 81 to port 27 of motor 5 and to port 27^a of motor 5^a, and channel 54 is connected to the left end of the bore of valve casing 68 so that ports 27 and 27^a are connected to the intake of pump 8 when valve plunger 67 is in the position shown in Fig. 1. Port 70 is connected by a channel 82 to port 25^a of motor 5^a and it has channel 53 connected thereto so that port 25^a is at all times subjected to the pressure created by pump 8.

Port 71 is connected by a channel 83 to port 25 of motor 5, ports 72 and 76 are connected by a channel 84 to channel 54 intermediate the ends thereof, port 73 is connected by a channel 85 to connector 36 on motor 5, port 74 has channel 56 connected thereto, port 75 is connected by a channel 86 to connector 34 on motor 5, port 77 is connected by a channel 87 to connector 36^a on motor 5^a, port 78 and the right end of the bore of valve casing 68 are connected to a drain channel 88 which discharges into reservoir 43, port 79 is connected by a channel 89 to connector 34^a on motor 5^a, and port 80 is connected by a channel 90 to channel 56 intermediate the ends thereof.

Valve plunger 67 is adapted to be shifted in one direction or the other by a piston 91 which is connected thereto and fitted in a cylinder 92 arranged upon the right end of valve casing 68. Liquid for operating piston 91 is supplied to cylinder 92 under the control of a pilot valve 93 which is arranged in the bore of a valve casing 94 having both ends thereof connected to drain channel 88 so that movement of valve 93 will not be hampered by entrapped liquid or gas.

Valve casing 94 has three annular grooves or ports 95, 96 and 97 formed in the wall of the bore thereof. Port 95 has gear pump channel 44 connected thereto, port 96 is connected by a channel 98 to the right end of cylinder 92, and port 97 is connected by a channel 99 to the left end of cylinder 92.

Pilot valve 93 may be shifted in any suitable manner such as in response to carriage 1 approaching the limit of its movement in each direction. Means are provided to compensate for the over run of carriage 1 but, since such means are well known and form no part of the present invention, they have been omitted from the drawings and valve 93 shown as having its stem connected by a link 100 to a lever 101 which has one of its ends pivoted upon a bracket 102 and its other end extending into the path of two dogs 103 and 104 carried by carriage 1.

Operation

Assuming that the several parts are in the positions shown in Fig. 1 and that pumps 8, 42 and 55 are running, the drive will function as follows:

Gear pump 42 will draw liquid from reservoir 43 and discharge it through channel 44 and resistance valve 45 into channel 46. The liquid discharged by gear pump 42 in excess of the liquid required to supercharge pump 8 will be exhausted through relief valve 47 into reservoir 43 so that gear pump 42 maintains a low or return pressure in channel 46 and a higher or gear pump pressure in channel 44. The gear pump pressure will extend from channel 44 through pilot valve casing 94 and channel 99 to the left end of servo-motor cylinder 92 and cause piston 91 to hold control valve plunger 67 in the position shown in Fig. 1. The return pressure will extend from channel 46 through channel 41, valve casing 49 and channel 54 to the left end of valve casing 68 and from channel 54 through channel 84 to ports 72 and 76.

Main pump 8 will discharge liquid through channel 40, valve casing 49 and channel 53 to port 70 in control valve casing 68 and maintain therein at all times a pressure proportional to the load on pump 8.

Pump 55 will draw liquid from channel 53 and discharge a part of it through resistance valve 57 back into channel 53 so that pump 55 is caused to maintain in channels 56 and 90 and in ports 74 and 80 a superpressure which is always greater than the main pump pressure by an amount equal to the resistance of valve 57.

With control valve plunger 67 in the position shown in Fig. 1, port 75 is open to port 74 and port 79 is open to port 80 so that superpressure can extend from port 74 through port 75, channel 86, connector 34 and passage 33 (Fig. 6) to the pressure grooves 31 in motor 5 and from port 83 through port 79, channel 89, connector 34^a and passage 33 to the pressure grooves 31 of motor 5^a.

Port 73 is open to port 72 and port 77 is open to port 76 so that return pressure can extend from port 72 through port 73, channel 85, connector 36 and passage 35 (Fig. 6) to the pressure grooves 32 of motor 5 and from port 76 through port 77, channel 87, connector 36^a and passage 35 to the pressure grooves 32 of motor 5^a.

Port 69 is open to return channel 54 so that return channel 54 is connected through valve casing 68, channel 81, main ports 27 and 27^a and passages 26 (Fig. 7) to the ports 23 of both motors.

Port 71 is open to port 70 so that motive liquid will flow through channels 83 and 82, main ports 25 and 25^a, passages 24 and ports 22 to the pressure sides of the chambers 21 (Fig. 5) of both motors.

The pressure of the motive liquid tends to move inward the vanes 20 whose outer ends extend into the pressure sides of the chambers 21 but the inner ends of those vanes are subjected to the superpressure in grooves 31 which holds them firmly against vane track 19 so that the motive liquid may act upon the outer end portions thereof and cause rotors 10 to rotate in a counterclockwise direction, the liquid carried across the sealing arcs of track 19 by the vanes being discharged into ports 23 and returned through the above described channels to the intake of pump 8.

Each vane 20 is held by the superpressure firmly against track 19 until the inner end of its slot moves out of registry with groove 31 at which time it has moved part way across the sealing arc, then

the liquid in the inner end of the vane slot is trapped therein during movement of the vane through a slight angular distance and then the inner end of the slot registers with a groove 32 which contains liquid at the return pressure, as previously explained, so that the vane is hydrostatically balanced and is held against the vane track solely by centrifugal force.

Rotation of rotors 10 in a counterclockwise direction causes drives 6 and 7 to rotate shaft 4 in a counterclockwise direction and thereby cause gear 3 to move rack 2 and carriage 1 toward the left at a speed proportional to the displacement of pump 8 relative to the combined displacements of motors 5 and 5^a.

As carriage 1 approaches the limit of its movement toward the left, dog 104 will engage lever 101 and cause it to shift pilot valve 93 to the position shown in Fig. 3, provision being made for over run of carriage 1 as mentioned above. Liquid from gear pump 42 will then flow through channel 44, valve casing 94 and channel 98 to the right end of cylinder 92 and cause piston 91 to shift control valve plunger 67 to the position shown in Fig. 2, the liquid expelled from cylinder 92 by piston 91 being conducted through channel 99, valve casing 94 and drain channel 88 into reservoir 43.

Shifting control valve plunger 67 to the position shown in Fig. 2 connects port 69 and port 70 and pump pressure will extend from port 70 through port 69 and channel 81 to main port 27 of motor 5 and to main port 27^a of motor 5^a, and pressure will extend from port 70 through channel 82 to main port 25^a of motor 5^a so that motor 5^a is short circuited and the outer ends of all of the vanes thereof are subjected to pump pressure. Also, port 80 is blocked and ports 77 and 79 are open to port 78 so that all of the pressure grooves 31 and 32 of motor 5^a are connected to drain channel 88 through the previously described channels. Since all of the vanes of motor 5^a have their outer ends subjected to pump pressure and their inner ends to zero pressure, they will be moved inward so that, when motor 5^a is driven by motor 5 as will presently be explained, rotor 10 of motor 5^a will spin idly and without displacing any liquid.

While motor 5^a has been shown as having both of its main ports connected to the pressure side of the main circuit and all of its pressure grooves connected to drain for the purpose of forcing the vanes inward, the vanes could be forced inward by connecting both main ports to the return side of the circuit and all of the pressure grooves to drain or by connecting both main ports to the pressure side of the circuit and all of the pressure grooves to the return side of the circuit.

When control valve plunger is in the position shown in Fig. 2, port 73 is open to port 74 instead of to port 72 and port 75 is open to port 76 instead of to port 74, so that the pressures in the pressure grooves of motor 5 are reversed, and port 71 is open to port 72 instead of to port 70 and port 69 is open to port 70 instead of to return channel 54 so that the flow of motive liquid to motor 5 is reversed. Consequently, motor 5 will operate in the previously described manner but in the opposite direction and move carriage 1 toward the right at a high speed which is proportional to the displacement of motor 5 relative to the displacement of pump 8. During movement of carriage 1 toward the right, drive 7 will rotate rotor 10 of motor 5^a which will spin idly since its vanes are fully retracted as previously explained.

As carriage 1 approaches the limit of its move-

ment toward the right, dog 103 will engage lever 101 and cause it to shift pilot valve 93 to the position shown in Fig. 1, provision being made for over run of carriage 1 as mentioned above. Liquid from gear pump 42 will then flow through channel 44, valve casing 94 and channel 99 to the left end of cylinder 92 and cause piston 91 to shift control valve plunger 67 to the position shown in Fig. 1, the liquid expelled from cylinder 92 by piston 91 being conducted through channel 98, valve casing 94 and drain channel 88 to reservoir 43.

Shifting control valve plunger to the position shown in Fig. 1 completes a cycle of operation and the several parts are then in position to start the next cycle of operation.

The drive described herein is susceptible of various modifications and adaptations without departing from the scope of the invention which is hereby claimed as follows:

1. A hydraulic drive for an element, comprising a first and a second rotary hydraulic motor mechanically connected to said element to drive the same and each having two ports, a pump for supplying liquid to said motors to energize the same, means for connecting one port of each motor to said pump to cause the liquid discharged thereby to energize both motors simultaneously and enable them to drive said element in one direction at a predetermined speed, means for connecting the other port of said first motor to said pump to cause the liquid discharged thereby to reverse said first motor and enable it to drive said element in the opposite direction at a higher speed and to also drive said second motor, and means operable simultaneously with said last named means for rendering said second motor incapable of pumping liquid.

2. A hydraulic drive for a reciprocable element, comprising a first and a second rotary hydraulic motor mechanically connected to said element to reciprocate the same and each having two ports, a pump for supplying liquid to said motors to energize the same, means responsive to said element approaching the limit of its movement in a given direction for connecting one port of each motor to said pump to cause the liquid discharged thereby to energize both motors simultaneously and enable them to drive said element in the opposite direction at a predetermined speed, means responsive to said element approaching the limit of its movement in said opposite direction for connecting the other port of said first motor to said pump to cause the liquid discharged thereby to reverse said first motor and enable it to drive said element in said given direction at a higher speed and to also drive said second motor, and means operable simultaneously with said last named means for rendering said second motor incapable of pumping liquid.

3. A hydraulic drive for an element, comprising a first and a second rotary hydraulic motor mechanically connected to said element to drive the same and each having two ports, a pump for supplying liquid to said motors to energize the same, means for connecting one port of each motor to said pump to cause the liquid discharged thereby to energize both motors simultaneously and enable them to drive said element in one direction at a predetermined speed, means for connecting the other port of said first motor to said pump to cause the liquid discharged thereby to reverse said first motor and enable it to drive said element in the opposite direction at a

higher speed and to also drive said second motor, and means operable simultaneously with said last named means for short circuiting said second motor.

4. A hydraulic drive for an element, comprising a first and a second rotary hydraulic motor mechanically connected to said element to drive the same and each having two ports, a pump for supplying liquid to said motors to energize the same, means for connecting one port of each motor to said pump to cause the liquid discharged thereby to energize both motors simultaneously and enable them to drive said element in one direction at a predetermined speed, means for connecting both ports of said second motor to each other and simultaneously connecting the other port of said first motor to said pump to cause the liquid discharged thereby to reverse said first motor and enable it to drive said element in the opposite direction at a higher speed and to also drive said second motor, and means operable simultaneously with said last named means for rendering said second motor incapable of pumping liquid.

5. A hydraulic drive for a reciprocable element, comprising a first and a second rotary hydraulic motor mechanically connected to said element to reciprocate the same and each having two ports, a pump for supplying liquid to said motors to energize the same, means responsive to said element approaching the limit of its movement in a given direction for connecting one port of each motor to said pump to cause the liquid discharged thereby to energize both motors simultaneously and enable them to drive said element in the opposite direction at a predetermined speed, means responsive to said element approaching the limit of its movement in said opposite direction for connecting both ports of said second motor to each other and simultaneously connecting the other port of said first motor to said pump to cause the liquid discharged thereby to reverse said first motor and enable it to drive said element in said given direction at a higher speed and to also drive said second motor, and means operable simultaneously with said last named means for rendering said second motor incapable of pumping liquid.

6. A hydraulic drive for an element, comprising a first and a second vane type hydraulic motor mechanically connected to said element to drive the same and each having two ports, each of said motors having a rotor provided with slidable vanes which must be urged outward in order to enable it to drive a load when supplied with motive liquid, a pump for supplying liquid to said motors to energize the same, means for connecting one port of each motor to said pump to cause the liquid discharged thereby to energize both motors simultaneously and enable them to drive said element in one direction at a predetermined speed, means for supplying to the inner end of each vane during at least a part of each revolution of said rotor liquid at a pressure higher than the pressure of the liquid which energizes said motor, means for connecting the other port of said first motor to said pump to cause the liquid discharged thereby to reverse said first motor and enable it to drive said element in the opposite direction at a higher speed and to also drive said second motor, and means operable simultaneously with said last named means for retracting all of the vanes of said second motor to thereby permit the rotor of said second motor to spin idly while being driven by said first motor.

said second motor to spin idly while being driven by said first motor.

7. A hydraulic drive for a reciprocable element, comprising a first and a second vane type hydraulic motor mechanically connected to said element to reciprocate the same and each having two ports, each of said motors having a rotor provided with slidable vanes which must be urged outward in order to enable it to drive a load when supplied with motive liquid, a pump for supplying liquid to said motors to energize the same, means responsive to said element approaching the limit of its movement in a given direction for connecting one port of each motor to said pump to cause the liquid discharged thereby to energize both motors simultaneously and enable them to drive said element in the opposite direction at a predetermined speed, means for supplying to the inner end of each vane during at least a part of each revolution of said rotor liquid at a pressure higher than the pressure of the liquid which energizes said motor, means responsive to said element approaching the limit of its movement in said opposite direction for connecting the other port of said first motor to said pump to cause the liquid discharged thereby to reverse said first motor and enable it to drive said element in said given direction at a higher speed and to also drive said second motor, and means operable simultaneously with said last named means for retracting all of the vanes of said second motor to thereby permit the rotor of said second motor to spin idly while being driven by said first motor.

8. A hydraulic drive for an element, comprising a first and a second vane type hydraulic motor mechanically connected to said element to drive the same and each having two ports, each of said motors having a rotor provided with slidable vanes which must be urged outward in order to enable it to drive a load when supplied with motive liquid, a pump for supplying liquid to said motors to energize the same, means for connecting one port of each motor to said pump to cause the liquid discharged thereby to energize both motors simultaneously and enable them to drive said element in one direction at a predetermined speed, means for supplying to the inner end of each vane during at least a part of each revolution of said rotor liquid at a pressure higher than the pressure of the liquid which energizes said motor, means for connecting both ports of said second motor to each other and simultaneously connecting the other port of said first motor to said pump to cause the liquid discharged thereby to reverse said first motor and enable it to drive said element in the opposite direction at a higher speed and to also drive said second motor, and means operable simultaneously with said last named means for retracting all of the vanes of said second motor to thereby permit the rotor of said second motor to spin idly while being driven by said first motor.

9. A hydraulic drive for a reciprocable element, comprising a first and a second vane type hydraulic motor mechanically connected to said element to reciprocate the same and each having two ports, each of said motors having a rotor provided with slidable vanes which must be urged outward in order to enable it to drive a load when supplied with motive liquid, a pump for supplying liquid to said motors to energize the same, means responsive to said element approaching the limit of its movement in a given

direction for connecting one port of each motor to said pump to cause the liquid discharged thereby to energize both motors simultaneously and enable them to drive said element in the opposite direction at a predetermined speed, means for supplying to the inner end of each vane during at least a part of each revolution of said rotor liquid at a pressure higher than the pressure of the liquid which energizes said motor, means responsive to said element approaching the limit of its movement in said opposite direction for connecting both ports of said second motor to each other and simultaneously connecting the other port of said first motor to said pump to cause the liquid discharged thereby to reverse said first motor and enable it to drive said element in said given direction at a higher speed and to also drive said second motor, and means operable simultaneously with said last named means for retracting all of the vanes of said second motor to thereby permit the rotor of said second motor to spin idly while being driven by said first motor.

10. A hydraulic drive for an element, comprising a first and a second vane type hydraulic motor mechanically connected to said element to drive the same and each having two ports, each of said motors having a rotor provided with slidable vanes which must be urged outward in order to enable it to drive a load when supplied with motive liquid, a pump for supplying liquid to said motors to energize the same, means for connecting one port of each motor to said pump to cause the liquid discharged thereby to energize both motors simultaneously and enable them to drive said element in one direction at a predetermined speed, means for supplying to the inner end of each vane during at least a part of each revolution of said rotors liquid at a pressure higher than the pressure of the liquid delivered to said ports, means for connecting the other port of said first motor to said pump to cause the liquid discharged thereby to reverse said first motor and enable it to drive said element in the opposite direction at a higher speed and to also drive said second motor, and means operable simultaneously with said last named means for connecting both ports of said second motor to said pump and for reducing the pressure at the inner ends of the vanes of said second motor below the pressure at the outer ends thereof to thereby cause said vanes to be moved inward and permit the rotor of said second motor to spin idly while being driven by said first motor.

11. A hydraulic drive for an element, comprising a first and a second vane type hydraulic motor mechanically connected to said element to drive the same and each having two ports, each of said motors having a rotor provided with slidable vanes which must be urged outward in order to enable it to drive a load when supplied with motive liquid, a pump for supplying liquid to said motors to energize the same, means for connecting one port of each motor to said pump to cause the liquid discharged thereby to energize both motors simultaneously and enable them to drive said element in one direction at a predetermined speed, means for supplying to the inner end of each vane during at least a part of each revolution of said rotors liquid at a pressure higher than the pressure of the liquid delivered to said ports, means for connecting both ports of said second motor to each other and simultaneously connecting the other port of said first motor to

said pump to cause the liquid discharged thereby to reverse said first motor and enable it to drive said element in the opposite direction at a higher speed and to also drive said second motor, and means operable simultaneously with said last named means for reducing the pressure at the inner ends of the vanes of said second motor below the pressure at the outer ends thereof to thereby cause said vanes to be moved inward and permit the rotor of said second motor to spin idly while being driven by said first motor.

12. A hydraulic drive for a reciprocable element, comprising a first and a second vane type hydraulic motor mechanically connected to said element to reciprocate the same and each having two ports, each of said motors having a rotor provided with slidable vanes which must be urged outward in order to enable it to drive a load when supplied with motive liquid, a pump for supplying liquid to said motors to energize the same, means responsive to said element approaching the limit of its movement in a given direction for connecting one port of each motor to said pump to cause the liquid discharged thereby to energize both motors simultaneously and enable them to drive said element in the opposite direction at a predetermined speed, means for supplying to the inner end of each vane during at least a part of each revolution of said rotors liquid at a pressure higher than the pressure of the liquid delivered to said ports, means responsive to said element approaching the limit of its movement in said opposite direction for connecting both ports of said second motor to each other and simultaneously connecting the other port of said first motor to said pump to cause the liquid discharged thereby to reverse said first motor and enable it to drive said element in said driven direction at a higher speed and to also drive said second motor, and means operable simultaneously with said last named means for reducing the pressure at the inner ends of the vanes of said second motor below the pressure at the outer ends thereof to thereby cause said vanes to be moved inward and permit the rotor of said second motor to spin idly while being driven by said first motor.

13. In a drive having a first and a second hydraulic motor mechanically connected to an element to drive the same and each including a stator having a chamber arranged therein, a cylindrical rotor arranged within said chamber and provided with a plurality of substantially radial vane slots, a substantially elliptical vane track arranged around said rotor, and vanes fitted in said slots and adapted to engage said track, said stator having a first and a second pair of diametrically opposed secondary ports communicating with said chamber, a first and a second main port communicating with said first and second pairs of secondary ports respectively and a first and a second pair of pressure grooves arranged inwardly from said first and second pairs of secondary ports respectively and communicating with the inner ends of said vane slots successively as said rotor rotates, the combination of a first channel, a second channel, a pump for supplying liquid to said channels, means for causing the pressure in said second channel to at all times exceed the pressure in said first channel, and a plurality of valve means operable to simultaneously connect said second main ports and said second pressure grooves to discharge, said first main ports to said first channel and said first pressure grooves to said second chan-

nel to thereby enable said motors to drive said element in one direction at a predetermined speed, said valve means being also operable in another position to simultaneously connect the first main port and the first pair of pressure grooves of said first motor to discharge, the second pair of pressure grooves of said first motor to said second channel, all of the pressure grooves of said second motor to discharge, the main ports of said second motor to each other and the second main port of said first motor to said first channel to thereby enable said first motor to drive said element in the opposite direction at a higher speed and the rotor of said second motor to spin idly.

14. In a drive having a first and a second hydraulic motor mechanically connected to an element to drive the same and each including a stator having a chamber arranged therein, a cylindrical rotor arranged within said chamber and provided with a plurality of substantially radial vane slots, a substantially elliptical vane track arranged around said rotor, and vanes fitted in said slots and adapted to engage said track, said stator having a first and a second pair of diametrically opposed secondary ports communicating with said chamber, a first and a second main port communicating with said first and second pairs of secondary ports respectively and a first and a second pair of pressure grooves arranged inwardly from said first and second pairs of secondary ports respectively and communicating with the inner ends of said vane slots successively as said rotor rotates, the combination of a first channel, a second channel, a pump for supplying liquid to said first channel, a second pump for drawing liquid from said first channel and discharging it into said second channel at a pressure which at all times exceeds the pressure in said first channel, and a plurality of valve means operable to simultaneously connect said second main port and said second pair of pressure grooves of each motor to discharge, said first main port of each motor to said first channel and said first pair of pressure grooves of each motor to said second channel to thereby enable both of said motors to drive said element in one direction at a predetermined speed, said valve means being also operable in another position to simultaneously connect the first main port and the first pair of pressure grooves of said first motor to discharge, the second pair of pressure grooves of said first motor to said second channel, all of the pressure grooves of said second motor to discharge, both main ports of said sec-

ond motor and the second main port of said first motor to said first channel to thereby enable said first motor to drive said element in the opposite direction at a higher speed and the rotor of said second motor to spin idly.

15. In a drive having a first and a second hydraulic motor mechanically connected to an element to reciprocate the same and each including a stator having a chamber arranged therein, a cylindrical rotor arranged within said chamber and provided with a plurality of substantially radial vane slots, a substantially elliptical vane track arranged around said rotor, and vanes fitted in said slots and adapted to engage said track, said stator having a first and a second pair of diametrically opposed secondary ports communicating with said chamber, a first and a second main port communicating with said first and second pairs of secondary ports respectively and a first and a second pair of pressure grooves arranged inwardly from said first and second pairs of secondary ports respectively and communicating with the inner ends of said vane slots successively as said rotor rotates, the combination of a first channel, a second channel, a pump for supplying liquid to said channels, means for causing the pressure in said second channel to at all times exceed the pressure in said first channel, a plurality of valve means, means responsive to said element approaching the limit of its movement in a given direction for operating said valve means to cause the same to simultaneously connect said second main port and said second pair of pressure grooves of each motor to discharge, said first main port of each motor to said first channel and said first pair of pressure grooves of each motor to said second channel to thereby enable both of said motors to move said element in the opposite direction at a predetermined speed, means responsive to said element approaching the limit of its movement in said opposite direction for operating said valve means to another position to cause the same to simultaneously connect the first main port and the first pair of pressure grooves of said first motor to discharge, the second pair of pressure grooves of said first motor to said second channel, all of the pressure grooves of said second motor to discharge, the main ports of said second motor to each other and the second main port of said first motor to said first channel to thereby enable said first motor to move said element in said given direction at a higher speed and to enable the rotor of said second motor to spin idly.

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