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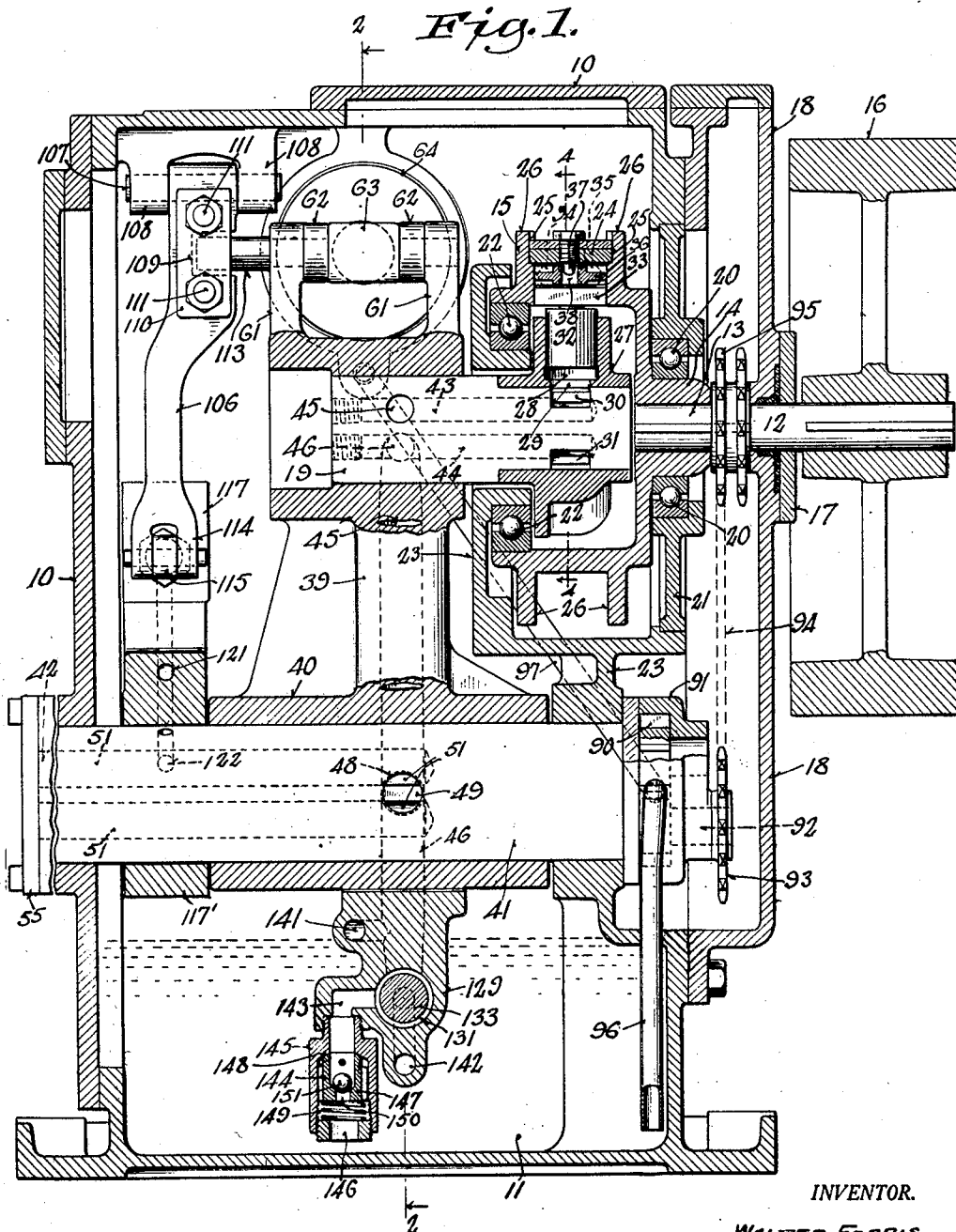
1,558,002

W. FERRIS

HYDRAULIC TRANSMISSION

Filed Dec. 21, 1923

3 Sheets-Sheet 1



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BY

*Ralph W. Brown*

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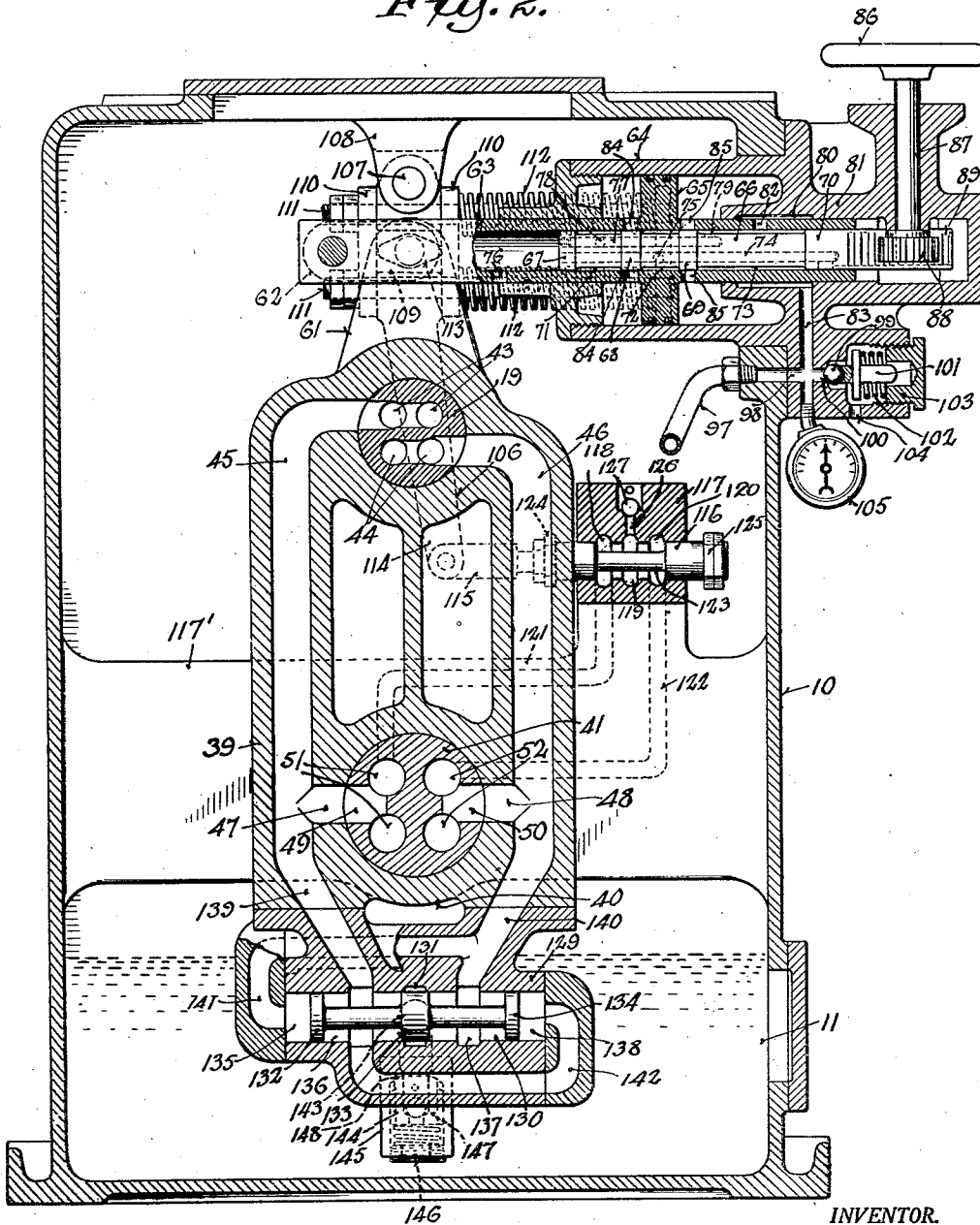
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## HYDRAULIC TRANSMISSION

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Fig. 2.



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HYDRAULIC TRANSMISSION

Filed Dec. 21, 1923

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*Fig. 3.*

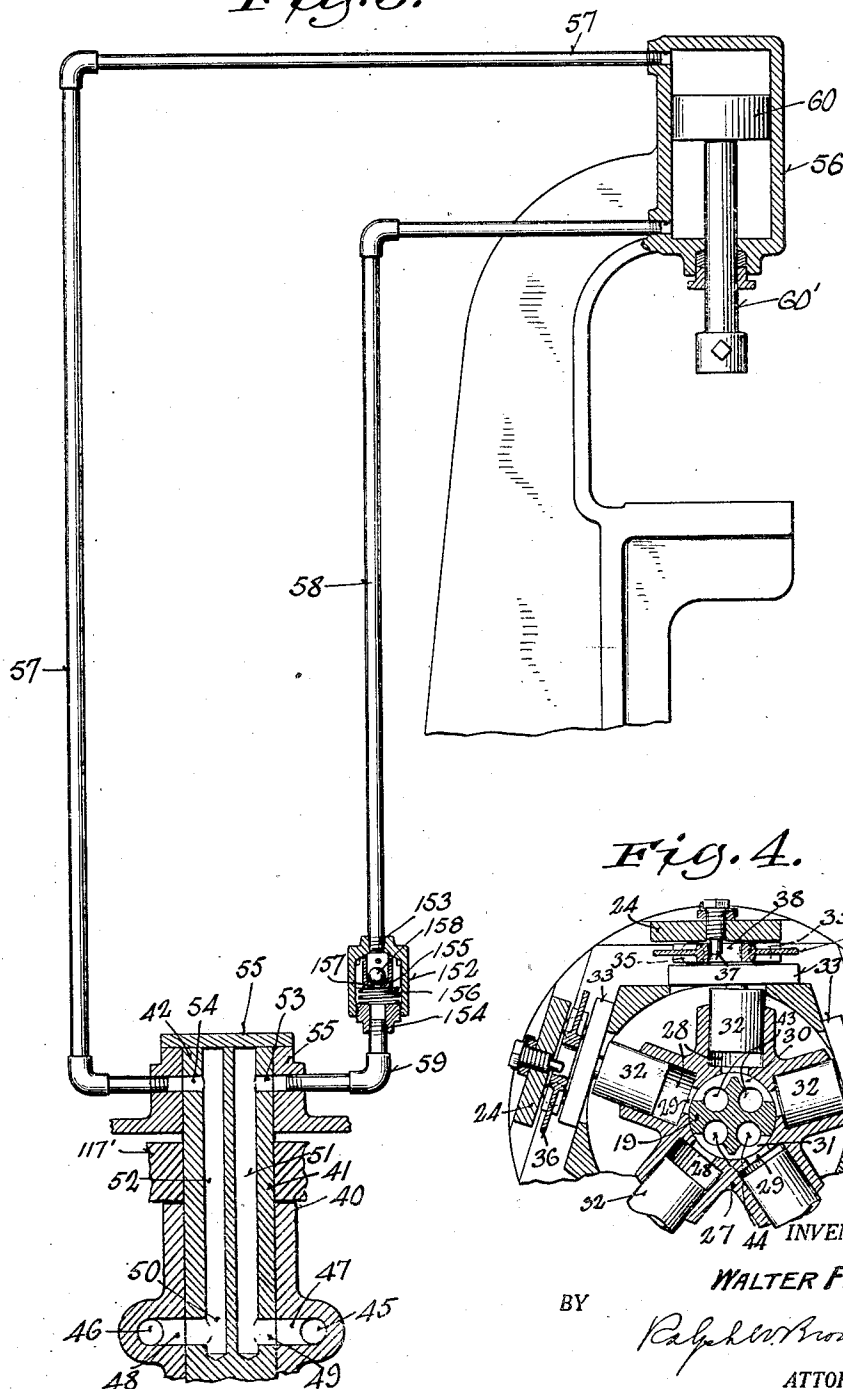
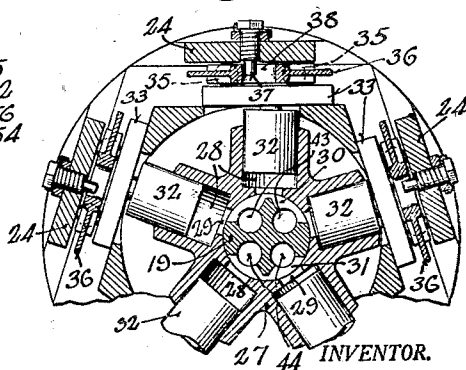


*Fig. 4.*



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# UNITED STATES PATENT OFFICE.

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OF MILWAUKEE, WISCONSIN, A CORPORATION OF WISCONSIN.

## HYDRAULIC TRANSMISSION.

Application filed December 21, 1923. Serial No. 682,056.

*To all whom it may concern:*

Be it known that I, WALTER FERRIS, a citizen of the United States, residing at Milwaukee, in the county of Milwaukee and State of Wisconsin, have invented a certain new and useful Improvement in Hydraulic Transmissions, of which the following is a full, clear, concise, and exact description, reference being had to the accompanying drawings, forming a part of this specification.

This invention relates to hydraulic transmission.

The general aim of the present invention is to improve the construction and operation of devices of this character.

A more specific object is to improve the construction and arrangement of the pump parts and their connections with the hydraulic circuit thereby to obtain a more convenient control of the rate and direction of fluid flow in the circuit.

Another object is the provision of improved means for taking care of differences in the volume of fluid in the two sides of the circuit, which ordinarily occur, for instance, in those systems in which a double acting piston is employed as a motor.

Another object is the provision of improved means for short circuiting the two sides of the circuit when the pump is set at zero stroke.

Another object is the provision of improved means for protecting the circuit from excessive pressures by automatically reducing the pump stroke upon increase of fluid pressure above a predetermined maximum.

In those instances in which the motor constitutes a vertically arranged piston and cylinder assembly there seems to be a tendency for the piston to creep downwardly by gravity. Another object of the present invention is the provision of a simple means for avoiding this difficulty.

Other objects and advantages will appear from the following description of an illustrative embodiment of this invention.

In the drawings:

Figure 1 is a sectional view through the casing of a pump comprising a part of a hydraulic transmission system embodying features of the present invention.

Figure 2 is a sectional view taken substantially along the line 2—2 of Figure 1.

Figure 3 is a view illustrating the circuit connections between the pump discharge and a vertical power cylinder of a typical hydraulic press.

Figure 4 is a fragmentary sectional view of the pump shown in section in Figure 1.

In the hydraulic transmission shown, the pump and associated parts are enclosed in a casing 10 having a basin or sump 11 in the base thereof containing a reserve supply of working fluid, preferably oil. A drive shaft 12, entering the casing 10, is keyed at its inner end 13 to a hub 14 of the pump driving cage 15, and at its outer end carries a heavy flywheel driving pulley 16. This shaft is journaled in a fixed bearing 17 in the wall of a housing 18 fixed to the outside of the casing 10.

The pump shown is similar in many respects to that described in my copending application, Serial No. 483,468, filed July 9, 1921. In this instance, however, the cage 15 rotates about a fixed axis and the pintle 19 is adjustable to vary pump displacement. The cage is journaled at one side in a fixed bearing 20 provided in a removable plate 21 forming one part of the casing wall, and at the other side in fixed bearings 22 provided in a rigid structure 23 formed within and as an integral part of the casing 10. The cage 15 carries adjacent its periphery a series of tangential reaction plates 24, removably fixed in opposed grooves 25 formed in the peripheral walls 26 of the cage. A cylinder barrel 27 having a radial series of cylinder bores 28 is supported by and rotates upon the pintle 19. Each cylinder bore has a port 29 adapted to register successively with ports 30 and 31 formed in the upper and lower surfaces of the pintle 19, during rotation of the cylin-

der barrel thereon. A piston 32 is closely fitted for reciprocation in each cylinder bore 28, and each carries a crosshead 33, disposed opposite to and parallel with one of the reaction plates 24. Two pairs of load transmitting antifriction rollers 34 and 35 are disposed between and in free rolling contact with each crosshead and cooperating reaction plate. The rollers of each set are freely rotatable in a roller cage 36, freely movable between the cooperating crosshead and reaction plate within limits defined by a retaining pin 37 anchored in the reaction plate and loosely engaging a slot 38 in the roller cage.

The pintle 19 is fixed in and carried by an upwardly projecting arm 39 having a hub 40 rockably mounted upon a shaft 41 extending across the casing 10, and having one end 42 fixed in one wall of the casing and the other end fixed in the rigid structure 23 hereinabove mentioned. Upper and lower pairs of passages 43 and 44 in the pintle communicate with the pintle ports 30 and 31, respectively, and with passages 45 and 46, respectively, leading downwardly along the arm 39 to passages 47 and 48 in opposite sides of the hub portion 40. Passages 47 and 48 communicate at all times through ports 49 and 50 with two vertical pairs of passages 51 and 52, respectively, extending longitudinally of the shaft 41. Passages 51 of one pair communicate with a port 53 formed in the end 42 of shaft 41 and passages 52 of the other pair communicate with a similar port 54.

A cap 55 covering the projecting end 42 of shaft 41 is fashioned to receive appropriate pipe connections through which the pump may be connected with any form of hydraulic motor desired. (See Figure 3.) In this instance, the motor shown is a vertical power cylinder 56 of a typical hydraulic press. A pipe 57 is shown connecting the upper end of this cylinder with the port 54 while the other port 53 is shown connected with the lower end of the cylinder through pipes 58 and 59 and a valve mechanism to be hereinafter described.

The arrangement of parts thus far described is such that when the pintle 19 is in a neutral position in which the axis of rotation of the cylinder barrel 27 is coincident with the axis of rotation of the driving cage 15, rotation imparted to the driving cage 15 by the pulley 16 and shaft 12 will cause the pistons 32 to travel about the pintle 19 without reciprocating in the cooperating cylinder bores 28 and pump displacement is zero. Any slight rocking of the arm 39 about the shaft 41 so as to shift the pintle 19 substantially horizontally in either direction from this neutral position will cause the pistons to reciprocate in their cylinder bores during rotation of the driving cage. When the pintle 19 is thus shifted in one direction to the eccentric position shown, for instance, in Figure 4, rotation of the cage 15 in a clockwise direction causes the pistons, during the upper half of their circular travel, to drive fluid from their cylinder bores through the ports 29 and pintle port 30 to and through the upper pair of passages 43 in the pintle. The fluid thus delivered by the pump passes downwardly through the passages 45 and 47 in the arm 39, through the passages 51 in the shaft 41, and thence through pipes 58 and 59 to the lower end of the power cylinder 56 causing the piston 60 therein to travel upwardly. At the same time, fluid discharged from the upper end of this cylinder passes through the pipe 57, passages 52, 48, 46 and the lower passages 44 in the pintle from which it is returned to the cylinder bores in the lower half of their circular travel through the pintle port 31. Similarly, by shifting the pintle to the other side of its neutral position, the cylinder bores during the upper half of their circular travel receive fluid from the upper pintle passages 43 and during the lower half of their travel discharge fluid into and through the lower pintle passages 44. Thus, by swinging the arm 39 the pintle may be shifted so as to vary the direction and rate of fluid flow delivered by the pump.

The position of the arm 39 and pintle 19 may be varied and controlled by any appropriate means. In this instance, the arm is provided with a pair of upstanding spaced ears 61 operatively connected through a pair of links 62 with a hollow plunger 63, mounted for lengthwise shifting in a control cylinder 64, secured within a wall of the casing 10. A piston 65 reciprocable in the cylinder 64 is formed integral with or fixed to the plunger 63. A pilot valve 66 within the plunger 63 is provided with four piston heads 67, 68, 69 and 70 closely fitted for sliding contact with the inner wall of the plunger, so as to form three annular chambers 71, 72 and 73 therein. A longitudinal duct 74 in the valve 66 communicates through a port 75 with the intermediate chamber 72, and through the head 67 with the interior of the hollow plunger 63, the plunger having a port 76 open at all times to the interior of the pump casing 10. A second longitudinal duct 77 in the valve communicates with the two annular chambers 71 and 73 through ports 78 and 79, respectively. An annular chamber 80 formed in the inner wall of a sleeve portion 81 of the control cylinder 64 communicates at all times with the chamber 73 through a port 82 and is supplied with fluid under pressure through a passage 83 from a convenient pressure source, such, for instance, as will be hereinafter described. Sets of ports 84

and 85 through the wall of the plunger 63 at opposite sides of the piston 65 are so spaced as to be simultaneously closed or simultaneously opened by the heads 68 and 69 of the pilot valve 66.

The arrangement of parts of this control mechanism are such that when the pilot valve 66 is shifted to the left, from the position shown in Figure 2, so that ports 84 and 85 are uncovered by heads 68 and 69, fluid under pressure passes from the chamber 80, through port 82, chamber 73, and ports 85 into the right end of control cylinder 64. Simultaneously, the left end of control cylinder is opened to exhaust through the ports 84, chamber 72, port 75, duct 74 and port 76. This, of course, results in movement of the piston 65 and plunger 63 to the left until the ports 84 and 85 are again covered by the heads 68 and 69. The extent of movement of the piston and plunger is, of course, dependent upon the extent to which the pilot valve has been shifted, this movement of the plunger being transmitted to the arm 39, and pintle 19, through the links 62 and ears 61. (Figure 1.) When the pilot valve 66 is shifted to the right, fluid under pressure is delivered to the left end of control cylinder 64 through the ports 84, chamber 71, port 78, duct 77, port 79, chamber 73 and port 82 from chamber 80, and the right end of cylinder 64 is opened to exhaust through ports 85, chamber 72 and duct 74. This results in movement of the piston 65 and plunger 63 to the right a distance corresponding to the extent of movement of the pilot valve. The pilot valve 66 may be shifted and controlled by any appropriate means as typified by the hand wheel 86 on a shaft 87 having a pinion and rack connection 88 with the stem 89 of the valve.

It will be noted that a variable displacement pump has been provided having the desired flexibility without requiring shifting of the drive shaft 12 or the use of flexible pipe connections.

During operation of the machine shown, fluid under substantially constant pressure is maintained in the chamber 80 by mechanism now to be described. Referring to Figure 1, this mechanism includes a gear pump 90 of a well known construction mounted in a casing 91 secured to the structure 23 adjacent the end of shaft 41. This pump is driven by a shaft 92, carrying a driving sprocket 93, connected through an appropriate chain 94 with a sprocket 95, keyed to the pump drive shaft 12. Fluid from the base of the sump 11 is lifted by the pump through a pipe 96 into the pump casing and is discharged by the pump through a pipe 97 into a passage 98 passing through a wall of the main pump casing 10. Passage 98 communicates with pas-

sage 83 leading to the chamber 80. A spring loaded relief valve determines the degree of fluid pressure existing in the passage 83 and chamber 80. This valve comprises a ball 99 normally seated over a port 100 in constant communication with passage 83. A plunger 101 under the pressure of a spring 102 tends to maintain the ball in port closing position. The spring reacts against a screw plug 103 which may be adjusted to any position to effect any desired tension in the spring. The quantity of fluid delivered to the passage 83 is preferably always in excess of that demanded by the control mechanism, the excess being discharged past the ball valve 99 and through the port 104.

In order to protect the hydraulic transmission against excessive pressures advantage is taken of the fact that in a pump of the type described, the pintle tends to shift toward its intermediate or zero pump stroke position by reason of an unbalanced thrust thereon resulting from the eccentricity of the cage 15 and cylinder barrel 27. It has been found that this thrust is substantially proportional to the working pressure in the hydraulic circuit. In utilizing this condition, the piston 65 is selected, of such diameter, that with a given fluid pressure in the chamber 80, the piston is capable of producing a thrust upon the plunger 63 sufficient to shift and retain the pintle 19 at any desired position of eccentricity, so long as the pressure in the main hydraulic circuit is below a desired maximum. Assuming, for instance, that the transmission is operating at a pressure below this maximum, with the pintle 19 in a position offset to the left of the zero pump stroke position, so that the pump thrust upon the pintle tends to force the pintle to the right toward the zero stroke position. The pintle is retained in this position by the pressure of the fluid in the right end of the cylinder 64 (Figure 2), the plunger 63 and pilot valve 66 being in the relative positions shown with the ports 84 and 85 covered by the heads 68 and 69 on the pilot valve. Now, should the pressure in the main hydraulic circuit increase over the allowed maximum, the pump thrust upon the pintle increases accordingly until this thrust transmitted to the plunger 63 and piston 65 is sufficient to force leakage of fluid from the right end of cylinder 64 and past the head 69 against the constant pressure of fluid maintained in the chamber 73 from the chamber 80. This leakage of fluid permits the piston 65 to move to the right, opening ports 85, and thus permitting further movement thereof and consequently the pintle to the right to reduce the pump stroke. Reduction of the pump stroke thus continues until the pressure in the hydraulic system has been reduced below the allowed

maximum. A similar reverse action occurs under excessive pressures when the pintle is on the right side of the zero stroke position.

When the maximum pressure in the main circuit is exceeded, the pump thrust upon the pintle shifts the plunger 63 and piston 65 to the left, the fluid passing from the left end of the control cylinder 64 through the ports 84, chamber 71, duct 77, to the chamber 80 against the fluid pressure therein. Since the main circuit pressure at which this action will occur is dependent upon the pressure maintained in the chamber 80, this maximum pressure may be predetermined by the adjusted tension in the spring 102 of the relief valve. For purposes of convenience, a pressure gauge 105 may be connected with the passage 83 to indicate the pressure therein and in the chamber 80.

Considerable difficulty has been experienced in attempting to shift the pintle into zero stroke position with the extreme accuracy required to reduce the flow in the main hydraulic circuit to absolute zero. Any deviation from this theoretically correct position results in undesirable creeping of the motor due to the slight flow in the circuit. In order to avoid this difficulty, provision is made for automatically short circuiting the two sides of the circuit as the pintle assumes zero stroke position. In this instance, the mechanism for this purpose includes a lever 106, depending from a pivot pin 107 fixed in appropriate lugs 108, formed upon the top wall of the main casing 10. Adjacent its upper pivoted end this lever is formed with an open ended horizontal cross-cut 109. A pair of plates 110, one at each side of the lever, cover the open ends of the cross-cut 109. These plates are carried by a pair of tension rods 111 extending loosely through the lever above and below the cross-cut. Coiled compression springs 112 on the rod 111 yieldably retain the plates 110 in contact with the sides of the lever. One of the ears 61 on the pintle supporting arm 39 carries an integral lug 113, projecting loosely into the cross-cut 109, between and in contact with the plates 110, so that as the arm 39 is swung in either direction from the neutral position shown in Figure 2, the lug 113, acting upon one or the other plates 110, tends to shift the lever 106 in the same direction.

The lower free end 114 of the lever 106 is connected to the stem 115 of a short circuiting valve 116 reciprocable in a valve block 117 secured to a rail 117' in the casing. The valve block shown is provided with three annular chambers 118, 119 and 120. Passages 121 and 122 connect the chambers 118 and 120, respectively, with the passages 51 and 52 constituting parts of the two sides of the main hydraulic circuit.

The valve 116 is provided with an intermediate reduced portion 123 permitting communication between the chambers 118 and 120 when the valve is in the intermediate position of Figure 2. With the valve in this position, the two sides of the main circuit are in open communication through the valve block. This is the position of the parts when the pintle is in zero pump stroke position.

When the arm 39 and pintle are shifted in either direction from this intermediate position, the lug 113, acting upon one of the plates 110, causes the lever 106 to swing about its pivot 107 until the lower end thereof has shifted the valve 116 into such position as to close communication between the chambers 118 and 120 in the valve block. Further movement of the valve 116 is prevented by the engagement of one of the stop collars 124 or 125, carried thereby, with the outer surface of the valve block. Since the lug 113 is so close to the pivot 107 of the lever as compared with the length thereof, this closing movement of the valve 116 is effected by a very slight movement of the pintle supporting arm. Further movement of the pintle may be continued, without movement of the lever 106, since either plate 110 is permitted to yield away from the lever against the pressure of the springs 112. It will thus be understood that the pintle may be shifted in either direction and to any desired extent to obtain the desired pump stroke, and during its initial movement the valve 116 is suddenly shifted so as to cut off communication of the two sides of the circuit through the valve block 117.

To insure against building up of pressure in the circuit during the short circuiting position of the valve 116, a discharge duct 126 is provided in communication with the intermediate chamber 119 in the valve block 117. This duct is controlled by a check valve 127 of any appropriate type.

Mechanism for taking care of the difference in volume of fluid in the two sides of the main hydraulic circuit will now be described. Such mechanism has particular utility when, as in this instance, the hydraulic motor is in the form of a double acting cylinder. For instance, as the piston 60 travels downwardly in the cylinder 56 a greater amount of fluid must be fed into the upper end of the cylinder than is discharged from the lower end thereof to compensate for the displacement of the piston rod 60' in the lower end of the cylinder only. In the pump shown, the mechanism for taking care of this fluid differential comprises a valve block 129 having a cylindrical bore 130 therein formed with an intermediate annular chamber 131. A piston valve having three piston heads 132, 133 and 134 and reciprocable in the block, divides the

bore 130 thereof into four chambers 135, 136, 137 and 138. The valve is shown in Figure 1 in intermediate position in which the intermediate head 133 closes communication between the chamber 131 and the rest of the bore 130. Chambers 136 and 137 are always in communication with the passages 45 and 46, respectively, through passages 139 and 140, and chambers 135 and 138 are always in communication with chambers 137 and 136, respectively, through passages 141 and 142. A passage 143 leads from the chamber 131 to the sump 11, preferably through a two way check valve 144 to be later described. The arrangement is such that when the passage 46 is carrying the working fluid, the pressure of this fluid is transmitted through passages 140 and 141 to chamber 135 causing the piston valve to shift to the right (Figure 2), thereby opening communication between the return side of the circuit and the sump through the passage 139, chamber 136, chamber 131 and the passage 143. This is the position of the piston valve when fluid is being delivered to the upper end of cylinder 56 causing the piston 60 to travel downwardly. As above pointed out, the upper end of the cylinder 56 demands a greater volume of fluid than that discharged by the lower end thereof. This deficiency of fluid volume is made up by fluid sucked up by the main pump into the passage 45 from the sump through the passage 143, chambers 131 and 136 and passage 139. When the displacement of the main pump is reversed so that the piston 60 is traveling upwardly, and passage 45 is carrying the working fluid and passage 46 the return fluid, the greater pressure in passage 45 is transmitted through the passages 139 and 142 to the chamber 138, to thereby shift the piston valve to the left, and thereby open communication between chambers 137 and 131. With the piston valve in this position, communication is established between what is then the return passage 46 and the sump, through the passages 140, chambers 137 and 131, and the passage 143. The excess fluid discharged by the upper end of the cylinder 56 is thus returned to the sump.

In order to insure sufficient pressure in the chamber 135 or 138 to effect reversal of the piston valve, when the pump is reversed, a two way check valve 144 is preferably provided between the passage 143 and the sump. The check valve shown comprises a valve casing 145 communicating with the pipe or passage 143 and with the sump 11 through a duct 146. A tubular valve 147 is yieldably maintained against its seat 148 under the pressure of a light spring 149, and adapted to open under the pressure of fluid passing downwardly through the passage 143. A tubular valve 147 is provided with a port 150 normally covered by a ball

valve 151, arranged to be lifted to open position by flow of fluid upwardly into the passage 143. It will be understood that the return side of the circuit, which is in open communication with the passage 143, becomes the working side of the circuit when the pump is reversed, and were it not for the check valve 144, the fluid in this side of the circuit would be free to escape into the sump without actuating the piston valve. The check valve serves to so check the flow of fluid in the passage 143 as to provide sufficient pressure in the working side of the circuit to shift the piston valve when the pump is reversed.

Provision is preferably made for preventing the piston 60 from creeping downwardly by gravity, as, for instance, when the motor circuit is short-circuited through the block 117 or otherwise. This is accomplished in this instance by the use of a two way check valve interposed between the pipes 58 and 59. This valve comprises a casing 152 having ports 153 and 154 in communication with pipes 58 and 59, respectively. A hollow valve 155 within the casing is yieldably retained in closed position by a spring 156. This valve is provided with a port 157 controlled by a ball check valve 158, arranged to open freely by the flow of fluid from pipe 59 to pipe 58, and to prevent flow through the hollow valve 155 in the other direction. The tension in spring 156 is such as to retain the hollow valve on its seat against the pressure of fluid in the pipe 58 due to the weight of piston 60, but to permit this valve to move from its seat under the fluid pressure in the pipe 58 during normal operation of the system. Thus, as the piston 60 is traveling downwardly under the working pressure in pipe 57, the fluid from the lower end of the cylinder passes from pipe 58 through port 153, around the valve 155, and through port 154 into pipe 59.

Various changes may be made in the embodiment of the invention hereinabove described, without departing from or sacrificing any of the advantages of the invention as defined in the appended claims.

I claim:

1. In a hydraulic transmission the combination of a hydraulic motor, a stationary member having a passage communicating therewith, a variable displacement pump, and a second member rockably associated with said stationary member for regulating pump displacement, said second member having a fluid passage therein communicating with said pump and with said first named passage.

2. In a hydraulic transmission the combination of a pump and a hydraulic motor driven by fluid delivered from said pump, and a hydraulic circuit between said pump and motor comprising a stationary member

and a second member rockably associated with said stationary member and operable to vary and control the relative displacements of said pump and motor.

5 3. In a hydraulic transmission the combination of a variable displacement pump, a stationary member having a fluid passage therein, and a second member rockably associated with said stationary member for  
10 regulating pump displacement, said second member having a fluid passage therein communicating with said pump and with said first named passage.

4. In a hydraulic transmission the combination of a variable displacement pump,  
15 a rockable member for regulating pump displacement having a fluid passage communicating with said pump, and a pivotal support for said member having a fluid  
20 passage communicating with said first named passage in all positions of said member.

5. In a hydraulic transmission the combination of a variable displacement pump,  
25 a rockable member for regulating pump displacement having separate passages for receiving fluid from and delivering fluid to said pump, and a pivotal support for said member having separate passages commu-  
30 nicating respectively with said first named passages in all positions of said member.

6. In a hydraulic transmission the combination of a variable displacement pump having a pintle adjustable with changes in  
35 pump displacement, said pintle having a passage through which fluid passes to or from said pump, a shaft having a fluid passage, and a link connecting said pintle and shaft and maintaining communication  
40 between said passages in all positions of said pintle.

7. A variable displacement pump or motor having a pintle adjustable with changes in pump displacement, and a support for  
45 said pintle rockable about an axis offset from the axis of said pintle.

8. In a hydraulic machine the combination of a radial series of piston and cylinder assemblies, a pintle having passages  
50 communicating therewith, and a pintle support having passages communicating with said first named passages and rockable about an axis offset from the axis of said  
55 pintle to vary the position of said pintle relative to said assemblies.

9. In a hydraulic machine the combination of a radial series of piston and cylinder assemblies, a pintle substantially centrally disposed within said series, and a  
60 support for said pintle rockable about an axis offset therefrom to vary the position of said pintle relative to said assemblies.

10. In a hydraulic machine the combination of a pintle, a series of piston and cylinder assemblies grouped about said pintle,

an adjustable support for said pintle, and hydraulic means for adjusting said support to vary the working stroke of said assemblies.

11. In a hydraulic machine the combination of a pintle, a series of piston and cylinder assemblies rotatable about said pintle, an adjustable support for said pintle, and hydraulic means for adjusting said support to thereby vary the center of rotation of  
70 said series of assemblies.

12. In a hydraulic machine the combination of a pintle, a series of piston and cylinder assemblies rotatable about said pintle, an adjustable support for said pintle,  
80 a source of fluid pressure, and means actuated from said pressure source for adjusting said support.

13. In a hydraulic machine the combination of a pintle, an adjustable support therefor, a series of piston and cylinder assemblies rotatable about said pintle, a pilot valve, and hydraulic means controlled by  
85 said valve for adjusting said support a distance corresponding to the extent of movement of said valve.

14. In a hydraulic transmission the combination of a variable displacement pump, a hydraulic circuit fed thereby, hydraulic means for regulating pump displacement,  
95 said means being of such capacity as to yield under pump thrust to reduce pump displacement when the pressure in said circuit exceeds a predetermined maximum.

15. In a hydraulic transmission the combination of a variable displacement pump, a hydraulic circuit fed thereby, a source of substantially constant fluid pressure,  
105 and a piston actuated from said pressure source for regulating pump displacement and yieldable when the pressure in said circuit exceeds a predetermined maximum to reduce pump displacement.

16. In a hydraulic transmission the combination of a variable displacement pump, a hydraulic circuit fed thereby, a pilot valve, and a fluid actuated piston for varying pump displacement in accordance with  
115 the extent of movement of said valve and automatically operable to reduce pump displacement when the pressure in said circuit exceeds a predetermined maximum.

17. In a hydraulic transmission the combination of a variable displacement pump, control means for regulating pump displacement, a hydraulic circuit fed by said pump, a by-pass connecting the sides of said circuit when said control means is substantially  
120 in zero displacement position, and means actuated only by the initial movement of said control means from zero stroke position for closing said by-pass.

18. In a hydraulic transmission the combination of a pump having an adjustable  
130

element for regulating pump displacement, control means therefor, a hydraulic circuit fed by said pump, short-circuiting means for said circuit, and means actuated by said element for controlling said short-circuiting means.

19. In a hydraulic transmission the combination of a variable displacement pump, control means therefor, a hydraulic circuit fed by said pump, short-circuiting means, actuating means therefor, and yieldable connections between said actuating means and said control means.

20. In a hydraulic transmission the combination of a variable displacement pump, control means therefor, a hydraulic circuit fed by said pump, a short-circuiting valve for said circuit, and yieldable connections between said control means and said valve for actuating said valve.

21. In a hydraulic transmission the combination of a variable displacement pump, control means therefor, a hydraulic circuit fed by said pump, a short-circuiting valve for said circuit, a lever for actuating said valve, and connections between said lever and said control means.

22. In a hydraulic transmission the combination of a variable displacement pump, control means therefor, a hydraulic circuit fed by said pump, a short-circuiting valve for said circuit, a lever, a pivotal support therefor, connections between said control means and said lever relatively near said support, and connections between said valve and said lever relatively far from said support.

23. In a hydraulic transmission the combination of a variable displacement pump, control means therefor, a hydraulic circuit, a short-circuiting valve, a lever, connections between said lever and said valve, yieldable connections between said lever and said control means, and a support for said lever pivotally connected therewith at a point relatively near said yieldable connection and far from said first named connection.

24. In a hydraulic transmission the combination of a variable displacement pump, a hydraulic circuit fed thereby, means for short circuiting said circuit when pump displacement is zero, and means for destroying the pressure in said circuit when said short circuiting means is effective.

25. In a hydraulic transmission the combination of a reversible flow pump, a hydraulic circuit communicating therewith having interchangeable high and low pressure sides of relatively varying capacities, a fluid reservoir, and means automatically operable to effect and maintain communication between said reservoir and that side of said circuit containing low pressure fluid.

26. In a hydraulic transmission the combination of a reversible flow pump, a hy-

draulic circuit communicating therewith having interchangeable high and low pressure sides of relatively varying capacities, a fluid reservoir, means automatically operable to effect and maintain communication between said reservoir and that side of said circuit containing low pressure fluid and means for yieldably resisting the flow of fluid through said means in one direction.

27. In a hydraulic transmission the combination with a hydraulic circuit including a cylinder, a reversible flow pump, and fluid connections between said pump and the opposite ends of said cylinder, of a piston in said cylinder, and means including a valve automatically operable to compensate for relative variations in the volumetric capacities of the two sides of said circuit.

28. In a hydraulic transmission the combination of a hydraulic circuit having interchangeable high and low pressure sides of relatively varying capacities, a fluid reservoir, a valve operated by the high pressure fluid in one side of said circuit for opening communication between said reservoir and the other side of said circuit, and a check valve associated with said first named valve.

29. In a hydraulic transmission the combination of a hydraulic circuit having interchangeable high and low pressure sides, a valve chest, a piston valve therein having end heads and an intermediate head, a port in said chest normally closed by said intermediate head, fluid passages leading from opposite sides of said circuit to said valve chest at opposite sides of said intermediate head, between said end heads, and means through which fluid pressure is applied to the end heads of said valve from said fluid passages, whereby a greater pressure in one side of said circuit will shift said valve to open communication between the other side of said circuit and said port.

30. In a hydraulic transmission the combination of a pump, a hydraulic motor, a hydraulic circuit connecting said pump and motor, and means for yieldably resisting the flow of fluid in one direction in said circuit to prevent creeping of said motor when said pump is ineffective.

31. In a hydraulic transmission the combination of a cylinder, a piston therein, a hydraulic circuit connected with said cylinder for operating said piston, and means for yieldably resisting a flow of fluid from one end of said cylinder to prevent undue creeping of said piston when said circuit is idle.

32. In a hydraulic transmission the combination of a substantially vertical cylinder, a piston therein, a hydraulic circuit connected with said cylinder for actuating said piston, and means for yieldably resisting a flow of fluid from the lower end of said

cylinder to prevent said piston from creeping by gravity therein.

33. In a hydraulic transmission the combination of a reversible pump, a closed hydraulic circuit communicating therewith having interchangeable high and low pressure sides of relatively varying capacities, a fluid reservoir, and means responsive to the difference in pressures between the sides of said circuit for maintaining communication between said reservoir and the low pressure side of said circuit.

34. In a hydraulic transmission the combination of a reversible flow pump, a closed hydraulic circuit having sides of relatively varying capacities connected to the opposite sides of said pump, a fluid reservoir, and valve mechanism responsive to the difference

in pressures between the sides of said circuit for connecting said reservoir with that side only of said circuit containing low pressure fluid.

35. In a hydraulic transmission the combination of a reversible flow pump having interchangeable intake and delivery passages, a closed hydraulic circuit having sides of relatively varying capacities connected to said pump passages, respectively, a fluid reservoir, and a valve connected across the sides of said circuit and automatically operable to maintain communication between said reservoir and the intake passage of said pump.

In witness whereof, I hereunto subscribe my name this 5th day of November, 1923.  
WALTER FERRIS.