

June 11, 1935.

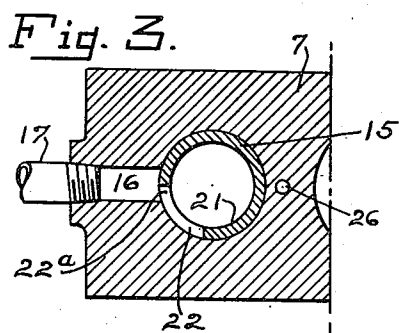
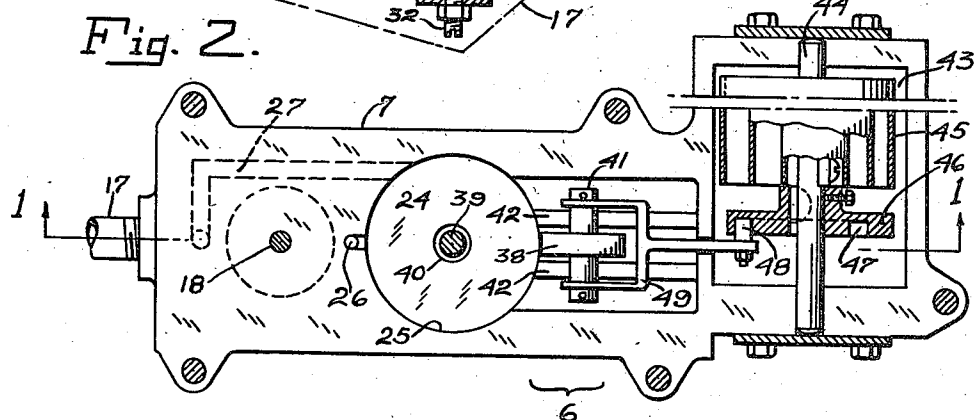
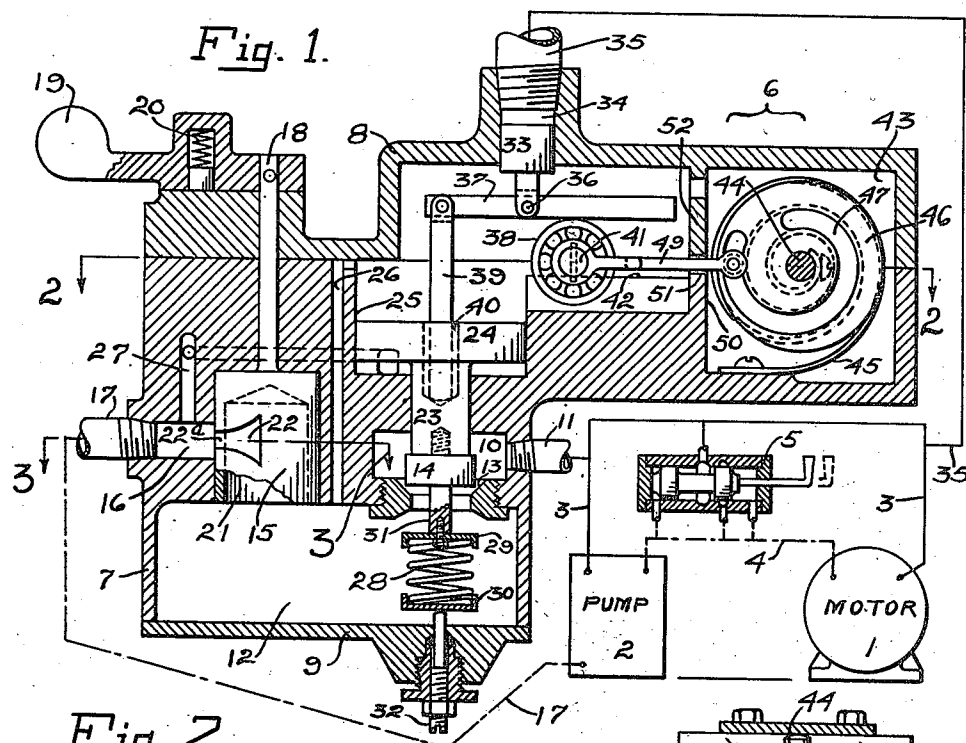
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2,004,522

SPEED CONTROLLER FOR HYDRAULIC MOTORS

Filed Sept. 19, 1932

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

Fig. 4.

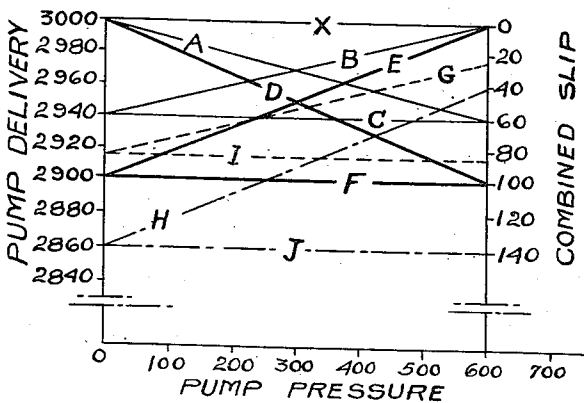
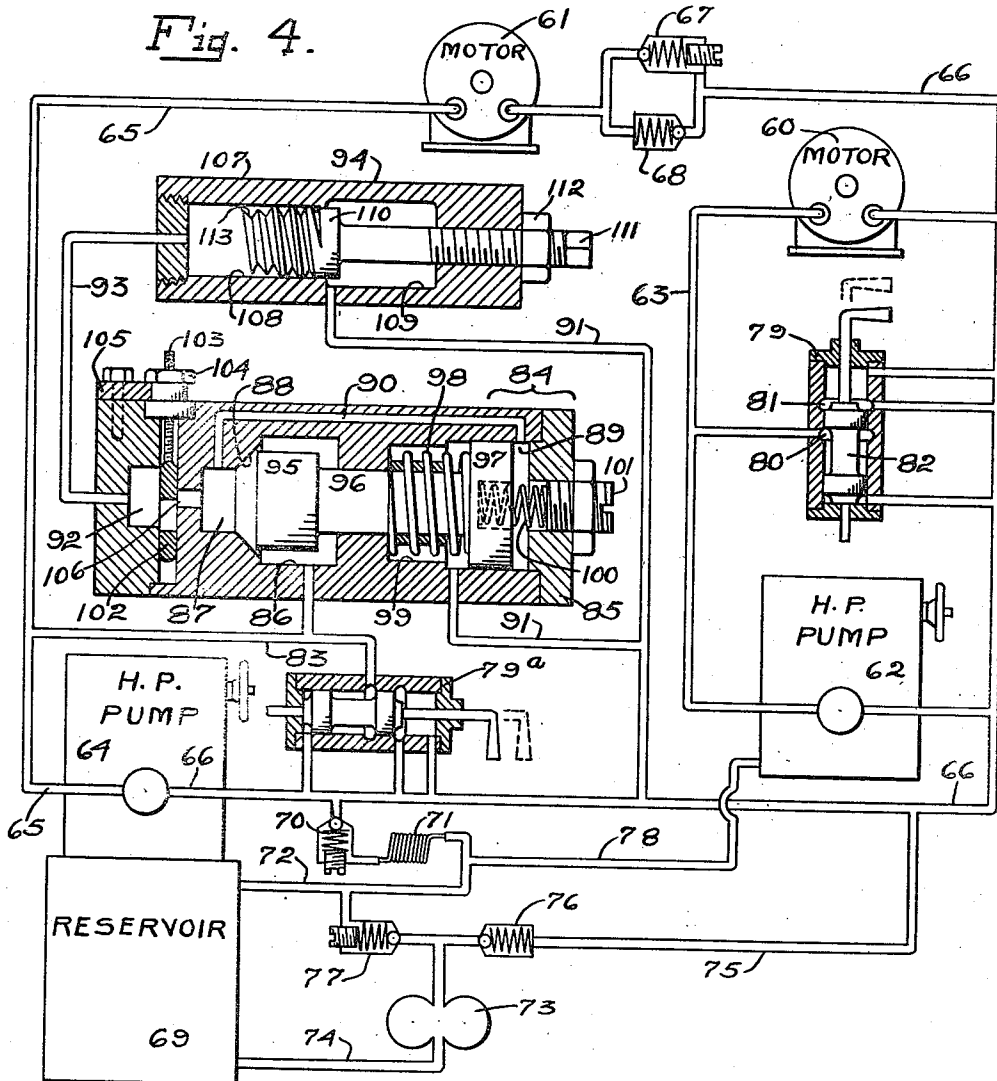


Fig. 5.

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UNITED STATES PATENT OFFICE

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SPEED CONTROLLER FOR HYDRAULIC MOTORS

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20 Claims. (Cl. 60—53)

This invention relates to hydraulic transmissions of the type in which a hydraulic motor is driven by liquid supplied thereto from a pump and in which pump pressure varies in proportion to the load imposed upon the motor.

The pump has as an inherent characteristic thereof an internal slip or leakage which reduces its net delivery. This slip is made up of several small factors, such as the small volumes which escape from between the cylinders and the pump valve, the small volumes which pass across the face of the pump valve from the discharge port to the intake port thereof, and any small volumes which may leak past the pistons. In addition, the net delivery of the pump is decreased by an apparent slip due to deflections of its parts, expansion of the pipes into which it delivers its output and to the compressibility of the driving liquid, which is ordinarily a good grade of lubricating oil.

If the motor is of the rotary type, it has a slip composed of substantially the same factors which compose the slip of the pump. If the motor is of the reciprocating type, its slip is due principally to any liquid which may escape past the motor piston.

Due to the compressibility of the liquid and to the fact that liquid will escape at an increased rate in response to an increase in pressure, the slip of both the pump and the motor at any given temperature will increase as the pump pressure increases and decrease as the pump pressure decreases. Consequently, the speed of the motor will decrease as the pressure increases and increase as the pressure decreases unless provision is made to compensate for variations in the combined slip of the pump and the motor due to variations in pressure.

The slip of both the pump and the motor is also affected by variations in temperature, due to the fact that the fluidity of the oil ordinarily employed as the driving medium increases as its temperature increases and decreases as its temperature decreases; an increase in temperature enabling the oil to escape more readily and at a greater rate. Consequently, the combined slip of the pump and the motor varies in accordance with variations in temperature and causes the speed of the motor at any given pressure to decrease as the temperature of the oil increases and to increase as the temperature of the oil decreases unless provision is made to compensate for the variations in the combined slip due to variations in the temperature of the oil.

A hydraulic transmission of this type is sometimes employed to operate a machine or a part thereof the speed of which should be maintained uniformly constant, and it is sometimes employed to operate a machine or a part thereof the speed of which should be maintained uniformly proportional to the speed of another machine or machine part.

The present invention has as an object to provide a hydraulic transmission with means for maintaining the speed of its motor constant at any given pressure or at any given temperature.

Another object is to provide a hydraulic transmission with means for compensating for the variations in the combined slip of the pump and motor due to variations in pressure.

Another object is to provide a hydraulic transmission with means for compensating for the variations in the combined slip of the pump and motor due to variations in both pressure and temperature.

Another object is to provide a hydraulic transmission with means for maintaining the speed of its motor uniformly proportional to the speed of another motor.

Another object is to provide a hydraulic transmission with a compensator which will vary a flow of liquid in response to variations in pressure.

Another object is to provide a hydraulic transmission with a compensator which will vary a flow of liquid in response to variations in the temperature of the liquid.

According to the invention in its general aspect, a predetermined volume of liquid delivered by a pump is bypassed or returned to the pump without passing through the motor driven by that pump, and this volume is varied inversely to the variations in the combined slip of the pump and motor.

According to the invention in another aspect, this volume of bypassed liquid is varied in response to variations in pump pressure.

According to the invention in another aspect, the volume of bypassed liquid is varied in response to variations in the temperature of the driving liquid.

The invention is illustrated by the embodiments shown in the accompanying drawings in which the views are as follows:

Fig. 1 is a diagrammatic representation of a hydraulic transmission in which a part of the liquid delivered by the pump is bypassed through a throttle valve unit which is responsive to variations in both pressure and temperature to

vary the rate at which liquid is bypassed, the valve unit being shown somewhat diagrammatically in central section as indicated by the line 1-1 of Fig. 2.

Fig. 2 is a sectional plan view taken on the line 2-2 of Fig. 1 and showing the valve unit with its cover removed.

Fig. 3 is a section on the line 3-3 of Fig. 1.

Fig. 4 is a diagrammatic representation of a hydraulic circuit in which the speed of one motor may be maintained proportional to the speed of another motor.

Fig. 5 is a chart illustrating a method of adjusting one of the transmissions shown in Fig. 4.

Figures 1-3

The transmission illustrated in these figures is shown provided with a rotary hydraulic motor 1 which is driven by liquid supplied thereto from a pump 2 through a supply pipe 3, and liquid is returned from the motor to the pump through a return pipe 4. The delivery of liquid is controlled by a valve 5 which is connected between the pipes 3 and 4 and may be operated to short circuit the pump and thereby prevent operation of the motor.

The pump may be of the type disclosed in Patent No. 1,619,200 issued March 1, 1927, to Walter Ferris, and the motor may be of the same type.

In order to prevent the combined slip of the pump and the motor from affecting the speed of the motor, a predetermined part of the liquid delivered by the pump is bypassed through a throttle valve or valve unit 6 which throttles or controls the flow of bypassed liquid and is responsive to variations in both temperature and pressure to vary the volume of the bypassed liquid inversely to the variation in slip caused by those variations in pressure and temperature.

The valve unit 6 has its mechanism arranged within and carried by a casing 7 which is provided upon opposite sides thereof with a cap 8 and a cover plate 9 and is shown with the cap 8 upward but, in practice, it is preferably so positioned that air or gas will not be trapped therein.

The casing 7 has a high pressure or inlet chamber 10 arranged therein and connected by a pipe 11 to the supply pipe 3 so that the pressure in the chamber 10 is at all times equal to pump pressure.

The high pressure chamber 10 communicates with a low pressure chamber 12 through a throttle valve which has an annular valve seat 13 carried by the casing, as by being threaded therein, and a valve piston 14 coacting with the seat 13 to restrict the flow of liquid from the chamber 10 to the chamber 12 and thereby cause a drop in pressure therebetween.

The low pressure chamber 12 communicates through a throttle valve 15 with an outlet 16 which is connected by an exhaust pipe 17 to the reservoir of the pump 2 for the free delivery thereto of the liquid bypassed through the valve unit.

The throttle valve 15 is of the cylindrical rotary type and is fitted in the casing 7 and provided with a stem 18 which extends upward through the cap 8 and is provided upon its upper end with an operating handle 19 having a friction device 20 arranged therein to engage the top of the cap 8 and retain the valve 15 in adjusted positions.

The valve 15 is provided with an axial recess or bore 21, which is open at all times to the

low pressure chamber 12, and with a peripheral opening 22 a part of which registers with the outlet 16 and thereby provides an orifice 22^a between the low pressure chamber 12 and the exhaust pipe 17.

The orifice 22^a may have its area varied by rotating the handle 19 to bring a greater or lesser area of the opening 22 into registry with the outlet 16, and the opening 22 is preferably so shaped that each degree of rotation of the handle 19 will be accompanied by a corresponding proportional increase in the rate at which liquid will flow through the orifice 22^a. For example, if a volume "a" is flowing through the orifice and rotation of the handle through a distance "n" will double this volume or increase it to "2a", an additional movement of the handle through another distance "n" will again double this volume or increase it to "4a" which is four times the original volume.

The flow of liquid through the valve unit is restricted in the first instance by the throttle valve 13-14, which permits a limited volume of liquid to flow from the high pressure chamber 10 to the low pressure chamber 12 and thereby causes a drop in pressure therebetween, and in the second instance by the valve 15 which restricts the flow of liquid from the chamber 12 to the outlet 16 and thereby causes a low pressure to be created in the chamber 12.

The valve 15 is adjusted to permit a predetermined volume of liquid to flow from the chamber 12 to the exhaust pipe 17 at a predetermined low pressure, and this volume will increase as the pressure in the chamber 12 increases and decrease as the pressure in the chamber 12 decreases, but it will not be materially affected by a change in temperature due to the fact that the rate of flow of liquid through an orifice changes but little with a change in the fluidity of the liquid.

The valve piston 14 is arranged within the high pressure chamber 10 upon the lower end of a plunger 23 which is fitted in the casing 7 and provided upon its upper end with a piston 24 which is fitted in a bore 25 formed in the casing 7.

The bore 25 has its upper end connected by a duct 26 to the low pressure chamber 12 and its lower end connected by a duct 27 to the outlet 16. The duct 26 permits the pressure prevailing in the low pressure chamber 12 to act upon the upper end of the piston 24 and urge it downward and thereby urge the piston 14 downward. The duct 27 prevents either a pressure or a vacuum from being formed in the lower end of the bore 25 by the piston 24 during reciprocation thereof and also prevents any pressure which might prevail in the drain pipe from having any effect upon the capacity of the valve unit 6.

The low pressure liquid acting upon the piston 24 and the high pressure liquid in the chamber 10 acting upon the upper end of the piston 14 both tend to move the piston 14 downward against the resistance of a helical compression spring 28 which is arranged within the chamber 12 between two spring retainers 29 and 30.

The spring retainer 29 is attached to the lower end of a stem 31 which is carried by the piston 14 upon the lower end thereof, and the spring retainer 30 is engaged upon its lower side by an adjusting screw 32 which extends through the cover plate 9 to adjust the tension of the spring 28.

The piston 14 is urged downward also by high pressure liquid acting upon a piston 33 fitted in a cylinder 34 which is formed in the cap 8 and connected by a pipe 35 to the pipe 3 so that the piston 33 is subjected at all times to pump pressure.

The piston 33 is connected by a pivot 36 to a lever 37 intermediate a ball bearing 38, which engages the lever 37 near one end thereof and functions as a fulcrum, and a vertical pressure bar 39 which has its upper end pivoted to the other end of the lever 37 and its lower end bearing upon the bottom of a vertical recess 40 formed in the plunger 23 and the piston 24.

The high pressure liquid acting upon the piston 33 exerts a downward force upon the plunger 23 through the lever 37 and the bar 39, the high pressure liquid in the high pressure chamber 10 exerts a downward force upon the top of the piston 14, and the low pressure liquid in the bore 25 exerts a downward force upon the piston 24. Consequently, the spring 28 must have sufficient strength to resist the sum of these forces in order to maintain an opening between the piston 14 and the valve seat 13 and thereby permit a flow of liquid through the valve unit.

The ball bearing 38 has its outer race in engagement with the underside of the lever 37 and its inner race fitted upon a shaft 41 which is supported upon the tops of two spaced horizontal ribs or ways 42 carried by the casing 7 upon opposite sides of the bearing 38.

The outer race of the bearing 38 may roll freely along the underside of the lever 37, the shaft 41 may roll freely along the ways 42, and the force exerted upon the plunger 23 through the lever 37 and the bar 39 will vary in accordance with the variation in the distance between the bearing 38 and the pivot 36.

The bearing 38 is moved toward and from the pivot 36 by a thermal device which is arranged in a compartment 43 formed by the casing 7 and its cap 8.

The thermal device is provided with a shaft 44 which has its ends journaled in the end walls of the compartment 43, a bi-metallic strip 45 which is wound spirally about the shaft 44 and has its inner end attached thereto and its outer end attached to a wall of the compartment 43, and a cam 46 which is fixed upon the shaft 44 and has a cam track 47 formed therein. The cam track 47 has a roller 48 arranged therein and rotatably supported upon one end of a connecting rod 49 which has its other end bifurcated and journaled upon the ends of the shaft 41.

The bi-metallic strip 45 is shown so wound about the shaft 44 that an increase in temperature will cause it to rotate the cam 46 in a clockwise direction in respect to Fig. 1, thereby causing the cam track 47 to move the roller 48 toward the shaft 44 to draw the roller bearing 38 away from the pivot 36 and enable the lever 37 to transmit to the bar 39 a greater part of the force exerted upon the piston 33 by the liquid in the cylinder 34.

For the purpose of illustration, the cam track 47 is shown as a simple curve but, in practice, it is made to conform to both the variation in the fluidity of the liquid and the degree of rotation of the cam 46 caused by temperature changes throughout a given temperature range.

In order to retain the roller 48 in the cam track 47 and to prevent the cam as it rotates

from swinging the connecting rod 49 vertically, the casing 7 is provided with a guide 50 which is arranged between the cam 46 and the ends of the ways 42 and has a notch 51 formed therein in which the rod 49 is retained by a partition 52 carried by the cap 8.

Assuming that the liquid is cold and that the pump is delivering liquid to the motor at a minimum pressure, the liquid in the high pressure chamber 10, the bore 25 and the cylinder 34 is urging the piston 14 downward against the spring 28 which is holding it a sufficient distance above the seat 13 to permit the passage therebetween of liquid at a volumetric rate which is at least as great as the combined slip of the pump and the motor at a given high pressure and a given high temperature.

The valve 15 restricts the discharge of liquid from the valve unit and causes a predetermined low pressure to be created in the chamber 12. This pressure extends through the passageway 26 and acts upon the piston 24, as previously described, and also causes the liquid to flow through the orifice 22^a at a predetermined volumetric rate which corresponds to or is greater than the combined slip of the pump and the motor when the same are operating at a given high pressure and a given high temperature.

While the resistance of the spring 28 will increase as it is compressed, the piston 14 moves such a short distance in varying the flow of liquid through the valve unit that the variation in the resistance of the spring 28 due to compression is so small that it will be disregarded in the following explanation of the operation of the valve unit.

Disregarding the variation in the resistance of the spring 28, the downward force exerted upon or transmitted to the piston 14 must equal the upward force exerted upon the piston 14 by the spring 28. Therefore, as the downward force exerted by the high pressure liquid increases, the downward force exerted by the low pressure liquid must decrease by a corresponding amount in order that the total downward force may at all times equal the upward force exerted by the spring 28.

An increase in pump pressure will increase the downward force exerted by the high pressure liquid and cause the piston 14 to move downward and reduce the flow of liquid from the chamber 10 to the chamber 12 until the pressure of the liquid in the chamber 12 and in the bore 25 has been reduced sufficiently to cause the downward force exerted by this low pressure liquid to be reduced by an amount equal to the increase in the downward force exerted by the high pressure liquid.

The piston 14 and the parts associated therewith thus function as a pressure inverter which varies the pressure in the chamber 12 inversely to variations in pump pressure.

The reduction in pressure in the chamber 12 causes the liquid to flow through the orifice 22^a at a reduced rate, and the difference between the volume passed through the orifice 22^a at this reduced pressure and the volume passed therethrough at the initial pressure is equal to the increase in the combined slip of the pump and the motor due to the increase in pressure.

If the pump pressure is then reduced, the downward force exerted by the high pressure liquid is reduced and the spring 28 moves the piston 14 away from the seat 13 and permits the flow of liquid therebetween to increase until the

pressure of the liquid in the chamber 12 and in the bore 25 has been increased sufficiently to cause the downward force exerted by this low pressure liquid to be increased by an amount equal to the decrease in the downward force exerted by the high pressure liquid.

The increase in the pressure of the liquid in the chamber 12 causes the liquid to flow through the orifice 22^a at an increased rate, and the difference between the volume passed through the orifice 22^a at this increased pressure and the volume passed therethrough at the previous pressure is equal to the decrease in the combined slip of the pump and motor due to the decrease in pressure.

Consequently, the volume of liquid actually used to move the motor pistons is exactly the same at all pressures, and the motor continues to operate at a constant speed irrespective of variations in motor load or pump pressure.

Operation of a hydraulic transmission ordinarily causes heat to be generated which raises the temperature of the driving liquid and increases its fluidity, thereby causing the slip of both the pump and the motor to increase as the temperature of the liquid increases.

This increase in temperature causes the bi-metallic strip 45 to unwind and rotate the shaft 44 and the cam 46, thereby causing the roller 48 to move along the cam track 47 and draw the ball bearing 38 away from the pivot 36 as previously described.

Moving the bearing 38 away from the pivot 36 enables the piston 33 to increase the force exerted by it upon the plunger 23, and this increase in force causes the piston 14 to move toward the seat 13 and reduce the flow of liquid therebetween until the pressure in the chamber 12 and in the bore 25 is reduced sufficiently to reduce the force exerted by the liquid in the bore 25 upon the piston 24 by an amount equal to the increase in the force exerted upon the plunger 23 by the piston 33.

The reduction in pressure in the chamber 12 causes the liquid to flow through the orifice 22^a at a reduced rate, and the difference between the volume of liquid passing through the orifice 22^a at this reduced pressure and the volume passing therethrough at the initial pressure is equal to the increase of the combined slip of the pump and the motor caused by the increase in temperature.

If the temperature of the liquid should then fall, the reduction in temperature would cause the bi-metallic strip 45 to wind up and rotate the cam 46 in the opposite direction, thereby reversing the process just described and causing the volume of liquid bypassed through the valve unit to be increased by an amount equal to the reduction in the combined slip of the pump and the motor caused by the reduction in temperature.

The volume of liquid bypassed through the valve unit at any given pressure is thus varied inversely to the variation in the combined slip of the pump and the motor caused by a variation in temperature, and the volume of liquid actually used to move the motor pistons is exactly the same at all temperatures. Consequently, the motor continues to operate at a constant speed irrespective of variations in the temperature of the driving liquid.

Further, the operation of the valve unit in response to a variation in temperature is independent of the operation thereof in response to

a variation in pressure, but the valve unit may respond simultaneously to variations in both temperature and pressure. Consequently, the variation in the volume of liquid bypassed by the valve unit is at all times inversely proportional to the variation in the combined slip of the pump and the motor caused by a variation in either temperature or pressure or in both temperature and pressure, and the motor will be driven at a constant speed which is unaffected by motor load or temperature.

Figure 4

A hydraulic transmission is sometimes employed to drive a mechanism the speed of which should be maintained constant relative to the speed of another mechanism, such as the several sections of a paper mill which are driven individually and should operate at speeds which are exactly proportional to each other at all times.

For example, three sections of a paper mill are ordinarily designated as the first dryer, the second dryer and the calender. Paper passes from the first dryer through the second dryer to the calender which maintains tension upon the paper and thereby assists in driving the second dryer. In some instances, if the paper is heavy and tough, the force exerted by the paper upon the second dryer is more than sufficient to drive it in which case the drive for the second dryer must act as a brake. If the paper breaks between the second dryer and the calender, the drive for the second dryer is deprived of the assistance of the calender and its load is increased, thereby causing it to slow down and allowing paper to accumulate between the first and second dryers.

It is essential, therefore, that the second dryer be operated at a speed which remains uniformly proportional to the speed of the first dryer.

This is accomplished by supplying liquid from a common source to the two pumps which drive the first and second dryer motors, so that liquid is delivered to both of these motors at approximately the same temperature, and by subtracting a predetermined volume of liquid from the output of the second dryer pump and varying this predetermined volume by an amount which is inversely proportional to the variation in the combined slip of the pump and motor caused by a variation in the load carried by the motor.

A hydraulic transmission, embodying the characteristics set forth above and capable of driving the second dryer of a paper mill, is shown schematically in Fig. 4 together with another transmission which may be employed to drive the first dryer of the paper mill.

One of these transmissions has a rotary hydraulic motor 60 which may be connected to the first dryer to drive the same, and the other transmission has a rotary hydraulic motor 61 which may be connected to the second dryer to drive the same.

The motor 60 is driven by liquid supplied thereto from a variable displacement pump 62 through a supply pipe 63, the motor 61 is driven by liquid supplied thereto from a variable displacement pump 64 through a supply pipe 65, and both motors discharge into a common return pipe 66 which connects the outlet of both motors to the intake of each pump.

As it may be necessary for the motor 61 to function sometimes as a brake to prevent the second dryer from being operated at too great

a speed by the calender, the return pipe 66 has a resistance valve 67 and a check valve 68 connected in parallel therein between the motor 61 and the motor 60.

5 The resistance valve 67 provides sufficient resistance to the discharge of liquid from the motor 61 to prevent the motor from being driven by the calender and thereby requires that the pump 64 develop a pressure which exceeds the pressure required to drive the motor 61 by the amount of pressure required to open the resistance valve.

The check valve 68 prevents liquid from being discharged from the motor 61 except through the resistance valve 67 but permits it to flow freely in the opposite direction in order that the motor may be reversed.

Operation of the transmission causes the liquid to become heated, and one transmission may generate more heat than the other. However, by exhausting the liquid from both motors into a common return pipe, the exhaust liquid from both motors is intermixed and delivered to both pumps at the same temperature. Consequently, when the slip of the motor and the pump of one transmission varies in response to a variation in temperature, the slip of the pump and the motor of the other transmission will vary a corresponding amount in response to the same variation in temperature.

In order to prevent the liquid from becoming overheated, an additional supply is maintained in a reservoir 69 into which heated liquid from the return pipe 66 is discharged at a given rate and from which cooled liquid is supplied to the return pipe.

Liquid is discharged from the return pipe 66 into the reservoir 69 through a low pressure check or resistance valve 70, a choke 71 and a discharge pipe 72 which are connected in series. The choke 71 limits the flow of liquid from the pipe 66 and determines the rate at which it will be discharged into the reservoir, and the resistance valve 70 prevents the liquid in the hydraulic circuit from flowing into the reservoir and air from entering the circuit when the transmission is not in operation.

The liquid which is discharged from the return pipe 66 is replaced by liquid delivered thereto from the reservoir 69 by a low pressure auxiliary or gear pump 73 one of which may be incorporated in either one or both of the pumps 62 and 64 as disclosed in Patent No. 1,619,200 referred to above.

The low pressure pump 73 draws liquid from the reservoir 69 through a suction pipe 74 and delivers it into a low pressure supply pipe 75 which connects the outlet of the pump 73 to the return pipe 66 and has a check valve 76 connected therein which allows liquid to flow freely into the return pipe 66 but prevents liquid from escaping from the pipe 66 through the pipe 75 when the transmission is idle.

The output of the pump 73 is somewhat greater than the total volume which escapes from the hydraulic circuit by leakage and through the discharge pipe 72, and the liquid delivered by the pump 73 in excess of requirements is exhausted into the reservoir 69 through a relief valve 77 which opens at a predetermined low pressure to permit the exhaust of this excess liquid and to enable the pump 73 to maintain in the return pipe 66 a predetermined low pressure which is higher than the pressure required to open the resistance valve 70.

The liquid which constitutes the external slip of the pump and the motor, or the liquid which escapes from the mechanisms of the pump and the motor in the housings thereof, is drained from each housing into the reservoir 69 directly, as shown by the position of the pump 64, or through suitable drain pipes such as the drain pipe 78 which connects the housing of the pump 62 to the discharge pipe 72. The drain pipes for the motors have been omitted from the drawing to avoid complicating the view.

The operation of the motor 60 is controlled by a control valve 79 which has its casing connected at each end thereof to the return pipe 66 and provided with an admission port 80, to which the supply pipe 63 is connected, and with an exit port 81 to which the return pipe 66 is connected.

The flow of liquid through the valve 79 is controlled by its plunger 82 which, when in the position shown in Fig. 4, closes communication between the pipes 63 and 66 and enables the pump 62 to deliver its output to the motor 60 to operate the same. When the plunger 82 is moved upward in respect to Fig. 4 until the port 80 is open to the port 81, the entire output of the pump 62 flows through the valve 79 to the return pipe 66 and no liquid is delivered to the motor 60 to operate the same.

The operation of the motor 61 is controlled by a control valve 79^a which is identical to the valve 79 and has its admission port connected to the supply pipe 65 by a pipe 83 and its exit port and the ends of its casing connected to the return pipe 66.

The valve 79^a is thus connected between the pipes 65 and 66 in the same manner that the valve 79 is connected between the pipes 63 and 66, and it functions to control the motor 61 in the same way that the valve 79 functions to control the motor 60.

When the pump 64 is delivering liquid to the motor 61, a part of its output is bypassed through a valve unit 84 which has been shown diagrammatically in Fig. 4 but which is ordinarily constructed similarly to the valve unit 6 shown in Fig. 1 except that the temperature control is omitted.

The valve unit 84 is shown provided with a casing 85 having formed therein an inlet or high pressure chamber 86, which is connected to the pipe 83, a low pressure chamber 87 which communicates with the high pressure chamber 86 through an annular valve seat 88 carried by the casing 85 at the discharge end of the chamber 86, a bore 89 which communicates at one end thereof with the low pressure chamber 87 through a duct 90 and at the other end thereof with the return pipe 66 through a pipe 91, and an outlet 92 which is connected by a pipe 93 to an adjustable choke 94.

The flow of liquid from the high pressure chamber 86 to the low pressure chamber 87 is controlled by a valve piston 95 which coacts with the valve seat 88 and forms a throttle valve therewith. The piston 95 is connected to one end of a plunger 96 which is fitted in the casing 85 to reciprocate therein and has a piston 97 arranged upon its other end and fitted in the bore 89 between the duct 90 and the pipe 91.

The valve piston 95 is urged away from the valve seat 88 by a helical compression spring 98 which abuts the piston 97 and is arranged in an annular recess 99 formed in the valve cas-

ing at the bottom of the bore 89 and surrounding the plunger 96.

The net tension of the spring 98 is adjusted by means of a spring 100 which engages the piston 97 in opposition to the spring 98 and has its tension adjusted by a screw 101 which is threaded into the end of the casing 85 and is retained in adjusted position by a suitable locknut.

The flow of liquid from the low pressure chamber 87 to the outlet 92 is controlled by a throttle valve 102 which is shown as being of the gate valve type and provided with a threaded stem 103 having an adjusting nut 104 threaded thereon and fitted in a suitable recess in the valve casing in which it is retained by a plate 105 fastened to the valve casing.

The valve 102 provides an orifice 106 between the low pressure chamber 87 and the outlet 92, and the nut 104 may be adjusted to regulate the area of this orifice and thereby limit and control the flow of liquid from the low pressure chamber 87 to the outlet 92.

The liquid entering the outlet 92 is discharged therefrom into the choke 94 through the pipe 93 which is connected to the casing 107 of the choke at the front end thereof. The casing 107 has formed therein an axial bore 108, which communicates with the pipe 93, and a counter-bore 109 which is concentric to the bore 108 and connected at its front end with the pipe 91.

Communication between the bore 108 and the counterbore 109, and consequently between the pipe 93 and the pipe 91 is controlled by a cylindrical choke member 110 which is fitted in the bore 108 and provided with a stem 111 which is threaded through the rear end of the casing 107 and provided with a suitable nut 112.

The choke member 110 is provided in its peripheral surface with a tapered spiral groove 113 which coacts with the wall of the bore 108 to provide a restricted passageway through which liquid must pass in flowing from the pipe 93 to the pipe 91.

When the member 110 is in the position shown in Fig. 4, it offers the greatest resistance to the flow of liquid through the choke as this liquid must pass through the entire length and through the smallest part of the groove 113. If the member 110 is moved rearward, the resistance to the flow of liquid is reduced for the reason that the small end of the groove 113 will then lie within the counterbore 109, and the effective length of the groove 113 will be reduced and the effective area thereof will be increased.

The choke 94 resists the discharge of liquid from the valve unit 84 and enables a low pressure to be created in the outlet 92, the throttle valve 102 resists the discharge of liquid from the chamber 87 and enables a low pressure to be created therein, the throttle valve 88—95 resists the flow of liquid from the chamber 86 to the chamber 87, and the total effect of these resistances determines the volume of liquid which will be bypassed from the supply pipe 65 to the return pipe 66 at any given temperature.

Liquid from the supply pipe 65 flows through the pipe 83 into the high pressure chamber 86, exerts upon the piston 95 a force which urges it toward the seat 88, and then passes between the piston 95 and the seat 88 into the chamber 87 where it meets the resistance of the throttle valve 102 and creates a low pressure in the chamber 87.

This low pressure extends through the duct 90 into the bore 89 and exerts upon the piston

97 a force tending to move the piston 95 toward the seat 88.

The hydraulic forces exerted upon the pistons 95 and 97 are opposed by the spring 98 the net resistance of which equals the sum of these hydraulic forces at all pressures and which is adjusted to maintain a predetermined opening between the piston 95 and the seat 88 at a predetermined pressure.

If the pump pressure increases, the liquid exerts a greater force upon the piston 95 and moves it closer to the seat 88 which reduces the rate of flow into the chamber 87 and causes a reduction in the pressure therein, thereby reducing the force exerted upon the piston 97 until the sum of the hydraulic forces exerted upon the pistons 95 and 97 equals the net resistance of the spring. The piston 95 will then remain in its new position and liquid will flow through the valve unit at a reduced rate.

The valve unit thus responds to a variation in pressure in exactly the same manner as the valve unit 6 and varies the volume of bypassed liquid by an amount which is inversely proportional to the variation in the combined slip of the motor 61 and the pump 64 caused by a variation in pump pressure.

The valve unit 84 may be adjusted to maintain the speed of the motor 61 constant at any given temperature and, as the pump 64 is adjustable, the speed of the motor 61 may be regulated to correspond exactly to the speed of the motor 60 or to be exactly proportional thereto, it being assumed that the motor 60 either operates under a constant load or that the transmission 60—62 is provided with means for maintaining the motor speed constant under varying loads.

Figure 5

The combined slip of the motor 61 and the pump 64, the volumes of liquid bypassed to compensate for this slip, and the resultant speeds of the motor 61 are indicated upon the chart.

The pump is driven at a constant speed and its displacement or theoretical delivery remains constant unless the pump is manually adjusted.

If the transmission could be operated at zero pressure, the slip would be zero for the reason that pressure is required to force liquid out from between the working parts of the pump and the motor. Therefore, at zero pressure, the motor would operate at the theoretical speed determined by the theoretical pump delivery. This speed would be constant and, if the pump were adjusted to have a theoretical delivery of 3000 cu. in. of liquid per minute, it would be proportional to that rate of delivery and could be represented upon the chart by the horizontal line X.

However, the pump cannot operate at zero pressure due to the resistance inherent in the hydraulic circuit and to the fact that some power is required to drive the motor even when it is running idle. Consequently, the liquid delivered by the pump is always under pressure and causes some slip but, for the purpose of illustration, both the volume of liquid delivered by the pump and the combined slip are shown on the chart and will be referred to hereinafter as varying upwardly from zero.

As the combined slip increases in response to an increase in pressure and thereby causes a corresponding decrease in motor speed, the speed of the motor at any pressure above zero will be the theoretical speed less the loss in

speed due to slip. If this speed is constant, it may be represented by a line drawn upon a chart parallel to the line X and spaced below it a distance corresponding to the amount of the slip.

Assuming that the pump is adjusted to have a theoretical delivery of 3000 cu. in. per minute and that the transmission has a slip of 60 units at 600 lb. pressure at a given low temperature, the slip at this temperature may be represented by the curve A which shows that the slip varies from 60 units at 600 lb. pressure to zero at zero pressure.

In order to prevent variations in pressure from causing variations in motor speed, it is necessary to adjust the choke and orifice combination until the volume of liquid bypassed at the given low temperature varies at the same rate as the variation in slip but inversely thereto. This volume of bypassed liquid may then be represented by the curve B which shows that this volume varies from zero at 600 lb. pressure to 60 units at zero pressure.

As the volume of bypassed liquid varies at the same rate as the variation in slip but inversely thereto, the volume of bypassed liquid added to the slip equals the 60 units of volume at all pressures within the given pressure range.

Therefore, the speed of the motor at the given low temperature and at all pressures within the given pressure rate will be constant and proportional to the difference between the theoretical pump delivery and the combined slip, or proportional to a delivery of 2940 cu. in. per minute. This speed may be represented by the line C which connects the lower ends of the curves A and B and is parallel to the line X, thus showing that the motor speed is constant and is less than the theoretical speed by the loss in speed represented by the distance between the line B and the line X.

Operation of the transmission causes the oil to become heated and the slip to increase as previously explained. If the oil becomes heated to a given high temperature and the slip at this high temperature is 100 units at 600 lb. pressure, it may be represented by the curve D which shows that the slip varies from 100 units at 600 lb. pressure to zero at zero pressure.

In order to obtain a constant motor speed at this higher temperature, it is necessary to increase the volume of bypassed liquid by an amount equal to the increase in slip caused by the increase in temperature and to vary the total volume of bypassed liquid inversely to the variation in slip caused by variation in pressure and at the same rate that the slip varies.

The volume of liquid which is bypassed at this higher temperature to obtain a constant motor speed may be represented by the curve E which shows that this volume must vary from zero at 600 lb. pressure to 100 units at zero pressure and vary in response to variations in pressure inversely at the same rate that the slip varies in response to variations in pressure.

Oil has the characteristic that a change in its temperature has but little effect upon the rate at which it will flow through an orifice but will have a material effect upon the rate at which it will flow through an elongated restricted passageway or choke.

If the discharge of liquid from the low pressure chamber 87 of the valve unit 84 was resisted solely by the orifice 106, the volume of bypassed liquid would not vary materially in re-

sponse to a variation in temperature and, if it was resisted solely by the choke 94, it would vary more in response to a variation in temperature than the slip would vary in response to the same variation in temperature for the reason that a part of the slip is due to compressibility of the oil and deflection of the pump and motor parts, and this part of the slip is not affected by a variation in temperature.

Therefore, the choke 94 and the throttle valve 102 are connected in series and adjusted to vary the volume of bypassed liquid in response to a variation in temperature at the same rate that the slip varies in response to the same variation in temperature.

The choke 94 is adjusted to vary the effective capacity of the groove 113 and the throttle valve 102 is adjusted to vary the area of the orifice 106 until the volume of oil bypassed is increased in response to an increase in temperature by an amount which is equal to the increase in slip due to the same increase in temperature. These adjustments are made by means of calibration charts previously prepared.

The volume of bypassed liquid thus varies in response to a temperature variation at the same rate that the slip varies in response to the same temperature variation and varies inversely in response to a pressure variation at the same rate that the slip varies in response to the same pressure variation.

Therefore, the speed of the motor at the higher temperature may be represented by the line F which connects the lower ends of the curves D and E and is parallel to the line X, thus showing that the motor speed is constant but slower than the speed at the lower temperature by the difference in speed represented by the distance between the lines C and F.

The transmission thus adjusted will maintain a constant motor speed at all pressures, but the motor speed will vary in response to a variation in temperature.

Assuming that the motors 60 and 61 should operate at the same speed, the pump 64 may now be adjusted to cause the motor 61 to operate at the same speed as the motor 60 at any given temperature. However, the motors might operate at different speeds at another temperature due to the fact that more power is ordinarily required to operate the first dryer than is required to operate the second dryer. Consequently, the first dryer transmission will operate at higher pressures than the second dryer transmission and will have a correspondingly greater slip with the resultant greater variation in speed in response to a variation in temperature. If it does not, a bypass choke may be readily connected between the supply pipe 63 and the return pipe 66 to increase the slip.

If the motors 60 and 61 do not operate at the same speeds at all temperatures, the net tension of the spring 98 may be adjusted to vary the volume of bypassed liquid until a variation in temperature will cause the same variation in the speed of both motors and the pump 64 may then be adjusted until the motor 61 is operating at the same speed as the motor 60.

For instance, if the motors operate at the same speed at a low temperature but the speed of the motor 61 is greater than the speed of the motor 60 at higher temperatures due to the greater slip of the first dryer transmission and the consequent greater variation in slip in response to a variation in temperature, the ten-

sion of the spring 98 may be increased to thereby increase the volume of bypassed liquid until the speed of the motor 61 is decreased in response to an increase in temperature at the same rate that the speed of the motor 60 decreases in response to the same increase in temperature, and then the pump 64 may be adjusted to increase its delivery until the motors are operating at the same speed at the higher temperature.

Adjusting the spring 98 does not affect the response of the throttle valve unit and choke combination to variations in pressure and temperature but simply causes a larger volume of oil to be bypassed at any given temperature and pressure, as indicated by the curves G and H on the chart which are drawn parallel, respectively, to the curves B and E and spaced vertically therefrom by a distance representing the additional volume of liquid caused to be bypassed by the adjustment of the spring 98.

These curves show that liquid will continue to be bypassed until a pressure is reached which is higher than the former maximum pressure, and that the volume of liquid bypassed at any given pressure is greater than formerly.

Consequently, with a given pump adjustment, the motor 61 will operate at a constant speed at any given temperature and this speed will be lower than its former speed at the same temperatures, as indicated by the lines I and J which are drawn horizontally from the ends of the curves G and H and represent, respectively, constant speed at the given low temperature and at the given high temperature.

The motor 61 will then operate at the same speed as the motor 60 at all temperatures and will operate at a constant speed at any given temperature irrespective of the variation in load.

The invention herein set forth is susceptible of various modifications and adaptations without departing from the scope thereof as hereafter claimed.

The invention is hereby claimed as follows:

1. A hydraulic transmission, comprising a hydraulic motor for carrying a variable load, a pump for delivering motive liquid to said motor to operate the same and having with said motor a combined slip which varies in accordance with the variations in the pressure created by said pump in response to variations in said load, and means for subtracting liquid from the output of said pump at a predetermined volumetric rate at a predetermined pump pressure and responsive to variations in pump pressure to vary said volumetric rate inversely to said variations in pump pressure.

2. A hydraulic transmission, comprising a hydraulic motor for carrying a variable load, a pump for delivering motive liquid to said motor to operate the same and having with said motor a combined slip which varies in accordance with the variations in the pressure created by said pump in response to variations in said load, a pressure pipe for directing liquid from said pump to said motor, a return pipe for returning liquid from said motor to said pump, and means connected between said pipes for bypassing liquid at a predetermined volumetric rate at a predetermined pump pressure and responsive to variations in pump pressure to vary said volumetric rate inversely to said variations in pump pressure.

3. A hydraulic transmission, comprising a hydraulic motor for carrying a variable load, a

pump for delivering motive liquid to said motor to operate the same and having with said motor a combined slip which varies in accordance with the variations in the pressure created by said pump in response to variations in said load, means for subtracting liquid from the output of said pump at a predetermined volumetric rate at a predetermined pump pressure and responsive to variations in pump pressure to vary said volumetric rate inversely to said variations in pump pressure, and means for adjusting the aforesaid means to vary said volume at any given pressure.

4. A hydraulic transmission, comprising a hydraulic motor for carrying a variable load, a pump for delivering motive liquid to said motor to operate the same and having with said motor a combined slip which varies in accordance with the variations in the pressure created by said pump in response to variations in said load, a pressure pipe for directing liquid from said pump to said motor, a return pipe for returning liquid from said motor to said pump, means connected between said pipes for bypassing liquid at a predetermined volumetric rate at a predetermined pump pressure and responsive to variations in pump pressure to vary said volumetric rate inversely to said variations in pump pressure, and means for adjusting the aforesaid means to vary said rate at any given pressure.

5. A hydraulic transmission, comprising a hydraulic motor for carrying a variable load, a pump for delivering motive liquid to said motor to operate the same and having with said motor a combined slip which varies in accordance with the variations in the pressure created by said pump in response to variations in said load, a throttle valve connected to said pump to subtract liquid from the output thereof at a predetermined volumetric rate at a predetermined pump pressure and responsive to variations in pump pressure to vary said volumetric rate inversely to said variations in pump pressure, and a secondary throttle valve and a choke connected in series with said throttle valve to restrict the discharge of liquid therefrom.

6. A hydraulic transmission, comprising a hydraulic motor for carrying a variable load, a pump for delivering motive liquid to said motor to operate the same and having with said motor a combined slip which varies in accordance with the variations in the pressure created by said pump in response to variations in said load, a pressure pipe for directing liquid from said pump to said motor, a return pipe for returning liquid from said motor to said pump, a throttle valve connected between said pipes to bypass liquid at a predetermined volumetric rate at a predetermined pump pressure and responsive to variations in pump pressure to vary said volumetric rate inversely to said variations in pump pressure, and a secondary throttle valve and a choke connected in series with said throttle valve to restrict the discharge of liquid therefrom.

7. The combination, with a hydraulic motor and a pump for delivering liquid to said motor to operate the same and having with said motor a combined slip which increases as the pressure created by said pump increases, of a throttle valve connected to the outlet of said pump for bypassing liquid at limited rates to reduce the rate at which liquid is delivered to said motor and having a plunger urged in one direction or the other in response to variations in

pump pressure to decrease the volumetric rate of said bypassed liquid as the pump pressure increases and to increase the volumetric rate of said bypassed liquid as the pump pressure decreases whereby said throttle valve varies the volumetric rate of said bypassed liquid inversely to the variations in the combined slip of said pump and motor and thereby tends to maintain the speed of said motor constant.

8. The combination, with a hydraulic motor, a pump for delivering liquid to said motor to operate the same and having with said motor a combined slip which increases as the pressure created by said pump increases, a pressure pipe for delivering liquid from said pump to said motor and a return pipe for returning liquid from said motor to said pump, of a throttle valve connected between said pipes for bypassing liquid at limited rates to reduce the rate at which liquid is delivered to said motor and having a plunger urged in one direction or the other in response to variations in pump pressure to decrease the volumetric rate of said bypassed liquid as the pump pressure increases and to increase the volumetric rate of said bypassed liquid as the pump pressure decreases whereby said throttle valve varies the volumetric rate of said bypassed liquid inversely to the variations in the combined slip of said pump and motor and thereby tends to maintain the speed of said motor constant.

9. The combination, with a hydraulic motor and a pump for delivering liquid to said motor to operate the same and having with said motor a combined slip which increases as the pressure created by said pump increases, of a throttle valve connected to the outlet of said pump for bypassing liquid at limited rates to reduce the rate at which liquid is delivered to said motor and having a plunger urged in one direction or the other in response to variations in pump pressure to decrease the volumetric rate of said bypassed liquid as the pump pressure increases and to increase the volumetric rate of said bypassed liquid as the pump pressure decreases whereby said throttle valve varies the volumetric rate of said bypassed liquid inversely to the variations in the combined slip of said pump and motor and thereby tends to maintain the speed of said motor constant, and a secondary throttle valve and a choke connected in series with said throttle valve for restricting the flow of liquid therefrom.

10. The combination, with a hydraulic motor, a pump for delivering liquid to said motor to operate the same and having with said motor a combined slip which increases as the pressure created by said pump increases, a pressure pipe for delivering liquid from said pump to said motor and a return pipe for returning liquid from said motor to said pump, of a throttle valve connected between said pipes for bypassing liquid at limited rates to reduce the rate at which liquid is delivered to said motor and having a plunger urged in one direction or the other in response to variations in pump pressure to decrease the volumetric rate of said bypassed liquid as the pump pressure increases and to increase the volumetric rate of said bypassed liquid as the pump pressure decreases whereby said throttle valve varies the volumetric rate of said bypassed liquid inversely to the variations in the combined slip of said pump and motor and thereby tends to maintain the speed of said motor constant, and a secondary throt-

tle valve and a choke connected in series with said throttle valve for restricting the flow of liquid therefrom.

11. The combination, with a hydraulic motor and a pump for delivering liquid to said motor to operate the same and having with said motor a combined slip which increases as the pressure created by said pump increases, of a throttle valve connected to the outlet of said pump for bypassing liquid at limited rates to reduce the rate at which liquid is delivered to said motor and having a plunger urged in one direction or the other in response to variations in pump pressure to decrease the volumetric rate of said bypassed liquid as the pump pressure increases and to increase the volumetric rate of said bypassed liquid as the pump pressure decreases whereby said throttle valve varies the volumetric rate of said bypassed liquid inversely to the variations in the combined slip of said pump and motor and thereby tends to maintain the speed of said motor constant, and means for adjusting said throttle valve to regulate the volume of liquid bypassed therethrough at any given pressure.

12. The combination, with a hydraulic motor and a pump for delivering liquid to said motor to operate the same and having with said motor a combined slip which increases as the pressure created by said pump increases, of a throttle valve for bypassing liquid at limited rates to reduce the rate at which liquid is delivered by said pump to said motor and comprising a casing having an inlet connected to the outlet of said pump and an outlet for the exhaust of liquid from said casing, a valve plunger controlling the flow of liquid through said casing and responsive to increases in pump pressure to reduce said flow, and a spring urging said valve plunger in a direction to increase said flow whereby said throttle valve varies the volumetric rate of said bypassed liquid inversely to the variations in the combined slip of said pump and motor and thereby tends to maintain the speed of said motor constant.

13. The combination, with a hydraulic motor and a pump for delivering liquid to said motor to operate the same and having with said motor a combined slip which increases as the pressure created by said pump increases, of a throttle valve for bypassing liquid at limited rates to reduce the rate at which liquid is delivered by said pump to said motor and comprising a casing having an inlet connected to the outlet of said pump and an outlet for the exhaust of liquid from said casing, a valve plunger controlling the flow of liquid through said casing and responsive to increases in pump pressure to reduce said flow, a spring urging said valve plunger in a direction to increase said flow whereby said throttle valve varies the volumetric rate of said bypassed liquid inversely to the variations in the combined slip of said pump and motor and thereby tends to maintain the speed of said motor constant, and means for adjusting the tension of said spring.

14. The combination, with a hydraulic motor and a pump for delivering liquid to said motor to operate the same and having with said motor a combined slip which increases as the pressure created by said pump increases, of a throttle valve for bypassing liquid at limited rates to reduce the rate at which liquid is delivered by said pump to said motor and comprising a casing having an inlet connected to the outlet of said

pump and an outlet for the exhaust of liquid from said casing, a valve plunger controlling the flow of liquid through said casing and responsive to increases in pump pressure to reduce said flow, and a spring urging said valve plunger in a direction to increase said flow whereby said throttle valve varies the volumetric rate of said bypassed liquid inversely to the variations in the combined slip of said pump and motor and thereby tends to maintain the speed of said motor constant, and means having a restricted orifice and an elongated restricted passageway connected in series for restricting the discharge of liquid from said casing.

15 15. A hydraulic transmission comprising a hydraulic motor for carrying a variable load, a pump for delivering oil to said motor to operate the same and having with said motor a combined slip which varies in accordance with the variations in the pressure and the temperature of said oil, and means connected to said pump for subtracting oil from the output thereof at a predetermined volumetric rate at a predetermined pressure and responsive to variations in pressure to vary said rate inversely to said variations in pressure and responsive to variations in temperature to vary said rate in accordance with said variations in temperature.

16. The combination, with a hydraulic transmission having a hydraulic motor for carrying a variable load and a pump for delivering oil to said motor to operate the same and having with said motor a combined slip which varies in accordance with the variations in the pressure and the temperature of said oil, of a valve unit connected to said pump for subtracting oil from the output thereof at a predetermined rate at a predetermined pressure and having means responsive to variations in pressure to vary said rate inversely to said variations in pressure and thermal means responsive to variations in temperature to effect operation of said pressure responsive means to vary said rate in accordance with said variations in temperature.

17. The combination, with a hydraulic motor and a pump for delivering oil to said motor to operate the same and having with said motor a combined slip which increases as the pressure created by said pump increases, of a throttle valve connected to the outlet of said pump for bypassing oil at limited rates to reduce the rate of which oil is delivered to said motor and having a plunger urged in one direction or the other in response to variations in pump pressure to decrease the volumetric rate of said bypassed oil as the pump pressure increases and to increase the volumetric rate of said bypassed oil as the pump pressure decreases whereby said throttle valve varies the volumetric rate of said bypassed oil inversely to the variations in the combined slip of said pump and motor and thereby tends to maintain the speed of said motor constant, a secondary throttle valve connected in series with said throttle valve for restricting the flow of oil therefrom, and means responsive to variations in temperature for effecting operation of said plunger to vary the volumetric rate of said bypassed oil in response to said variations in temperature.

18. The combination, with a hydraulic motor and a pump for delivering liquid to said motor to operate the same and to create in said motor fluid pressures which vary in accordance with the variations in the load carried by said motor and thereby cause said pump and said

motor to have a combined slip which varies in accordance with variations in said load, of means for preventing the speed of said motor from varying in response to variations in motor load and comprising a throttle valve casing having a piston chamber and communicating high and low pressure chambers, means for connecting said high pressure chamber to the outlet of said pump, means providing a restricted passageway for the discharge of liquid from said low pressure chamber and for limiting the rate of said discharge to enable liquid delivered from said high pressure chamber to said low pressure chamber to create a low pressure therein, a throttle valve plunger fitted in said casing to control the flow of liquid from said high pressure chamber to said low pressure chamber and having a piston fixed thereon and fitted in said piston chamber, a spring urging said plunger in a direction to open communication between said pressure chambers, a high pressure surface arranged upon said plunger in a position to be acted upon by the liquid in said high pressure chamber and urged thereby in a direction to cause said plunger to close communication between said pressure chambers, means providing open communication between said low pressure chamber and one end of said piston chamber to enable the low pressure prevailing in said low pressure chamber to act upon said piston and urge said plunger in the direction to close communication between said pressure chambers, and means for connecting the other end of said piston chamber to an exhaust to permit said piston to be moved by said low pressure; the areas of said high pressure surface and said piston being so proportioned in respect to the tension of said spring that the forces exerted thereon in response to a predetermined low pump pressure will hold said plunger in a position to permit a predetermined volume of liquid to be subtracted from the delivery of said pump at said predetermined low pump pressure and delivered into said low pressure chamber to create a low pressure therein and the forces exerted thereon in response to an increase in pump pressure will move said plunger against the resistance of said spring to reduce the volume of liquid subtracted from the delivery of said pump by an amount equal to the increase in said combined slip due to said increase in pump pressure.

19. The combination, with a hydraulic transmission having a hydraulic motor for driving a load and a pump for supplying motive liquid to said motor to drive the same at a uniform speed at a given temperature and having with said motor a slip which varies in accordance with variations in the temperature of said liquid and thereby causes a variation in the speed of said motor, of a second hydraulic motor for driving a variable load at a speed proportional to the speed of said first load, a second pump for supplying motive liquid to said second motor to drive the same and having with said second motor a slip which varies in accordance with variations in pressure created by said second pump in response to variations in said variable load and in accordance with variations in the temperature of said liquid, means for intermixing the liquid discharged from both of said motors and delivering said intermixed liquid to both of said pumps, and means for subtracting liquid from the output of said second pump at a predetermined volumetric rate at a predetermined temperature and a predetermined pressure and

responsive to variations in the pressure of said liquid to vary said volumetric rate inversely to the variations in the slip of said second pump and motor caused by said variation in pressure to thereby maintain the speed of said second motor proportional to the speed of said first motor.

20. The combination, with a hydraulic transmission having a hydraulic motor for driving a load and a pump for supplying motive liquid to said motor to drive the same at a uniform speed at a given temperature and having with said motor a slip which varies in accordance with variations in the temperature of said liquid and thereby causes a variation in the speed of said motor, of a second hydraulic motor for driving a variable load at a speed proportional to the speed of said first load, a second pump for supplying motive liquid to said second motor to drive the same and having with said second motor a slip which varies in accordance with

variations in pressure created by said second pump in response to variations in said variable load and in accordance with variations in the temperature of said liquid, means for intermixing the liquid discharged from both of said motors and delivering said intermixed liquid to both of said pumps, means for subtracting liquid from the output of said second pump at a predetermined volumetric rate at a predetermined temperature and a predetermined pressure and responsive to variations in the pressure of said liquid to vary said volumetric rate inversely to the variations in the slip of said second pump and motor caused by said variation in pressure to thereby maintain the speed of said second motor proportional to the speed of said first motor, and means connected to said second motor to enable the same to function as a brake upon said second load.

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