

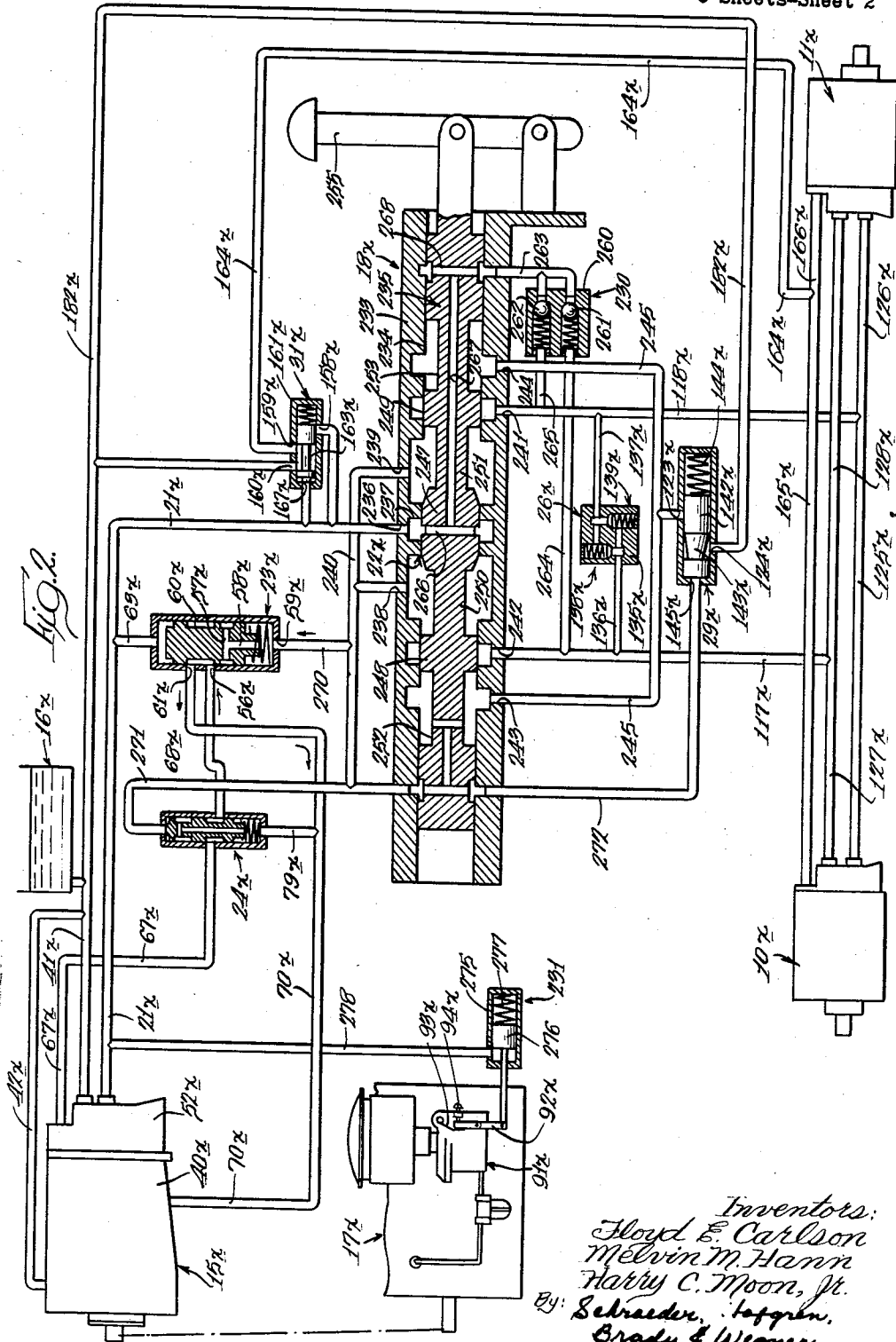
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HYDRAULIC TRANSMISSION

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5 Sheets-Sheet 2



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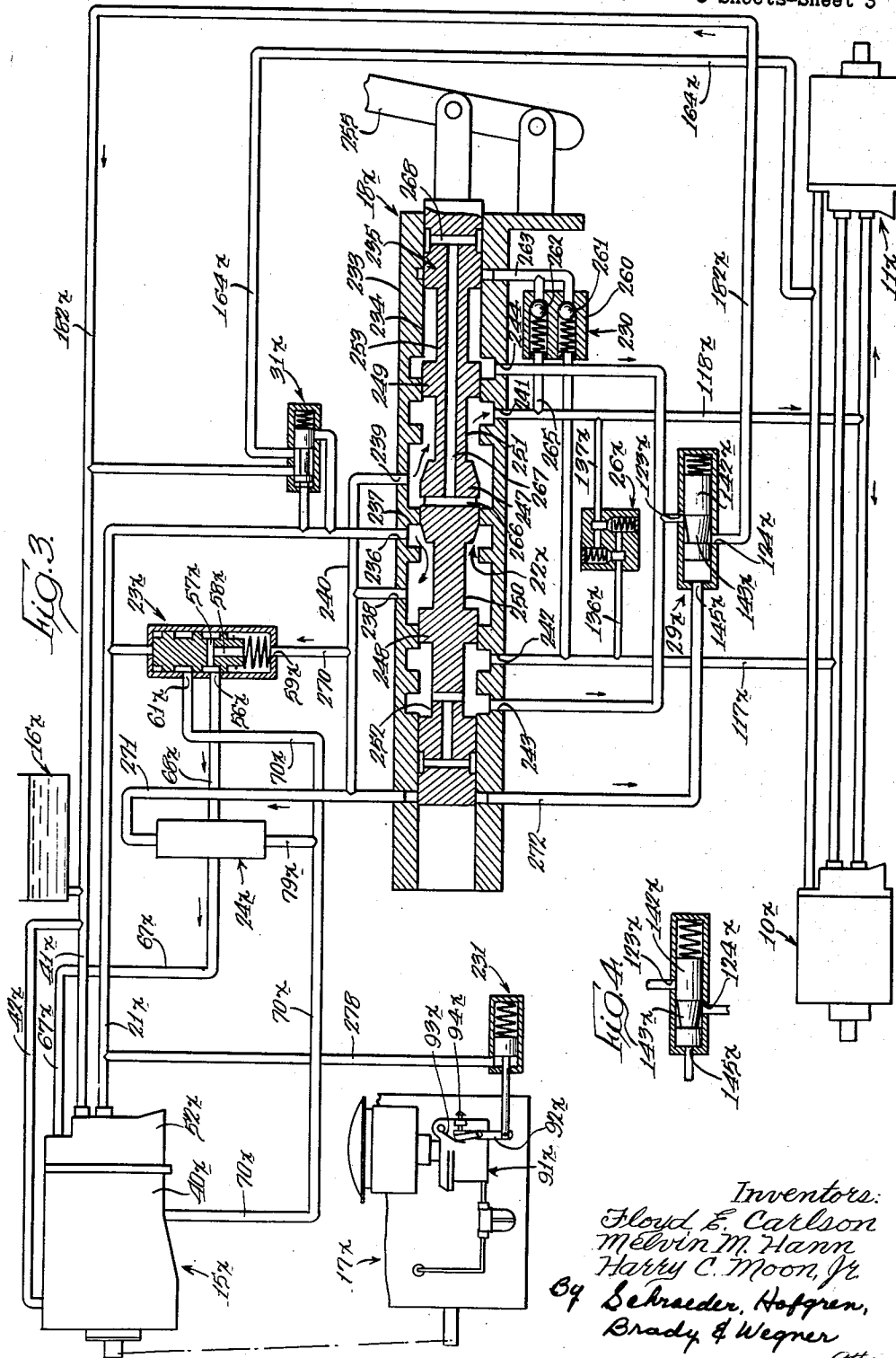
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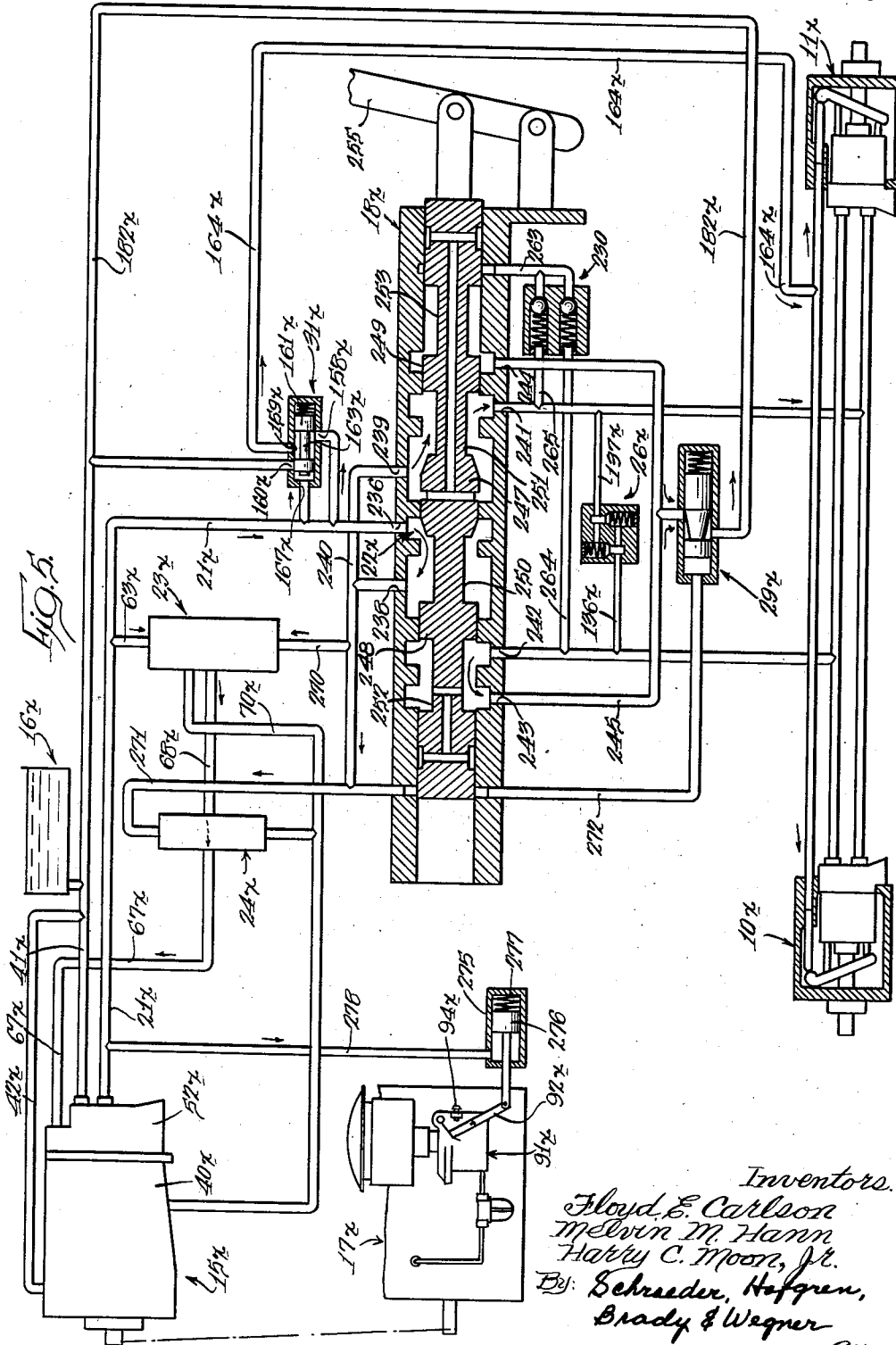
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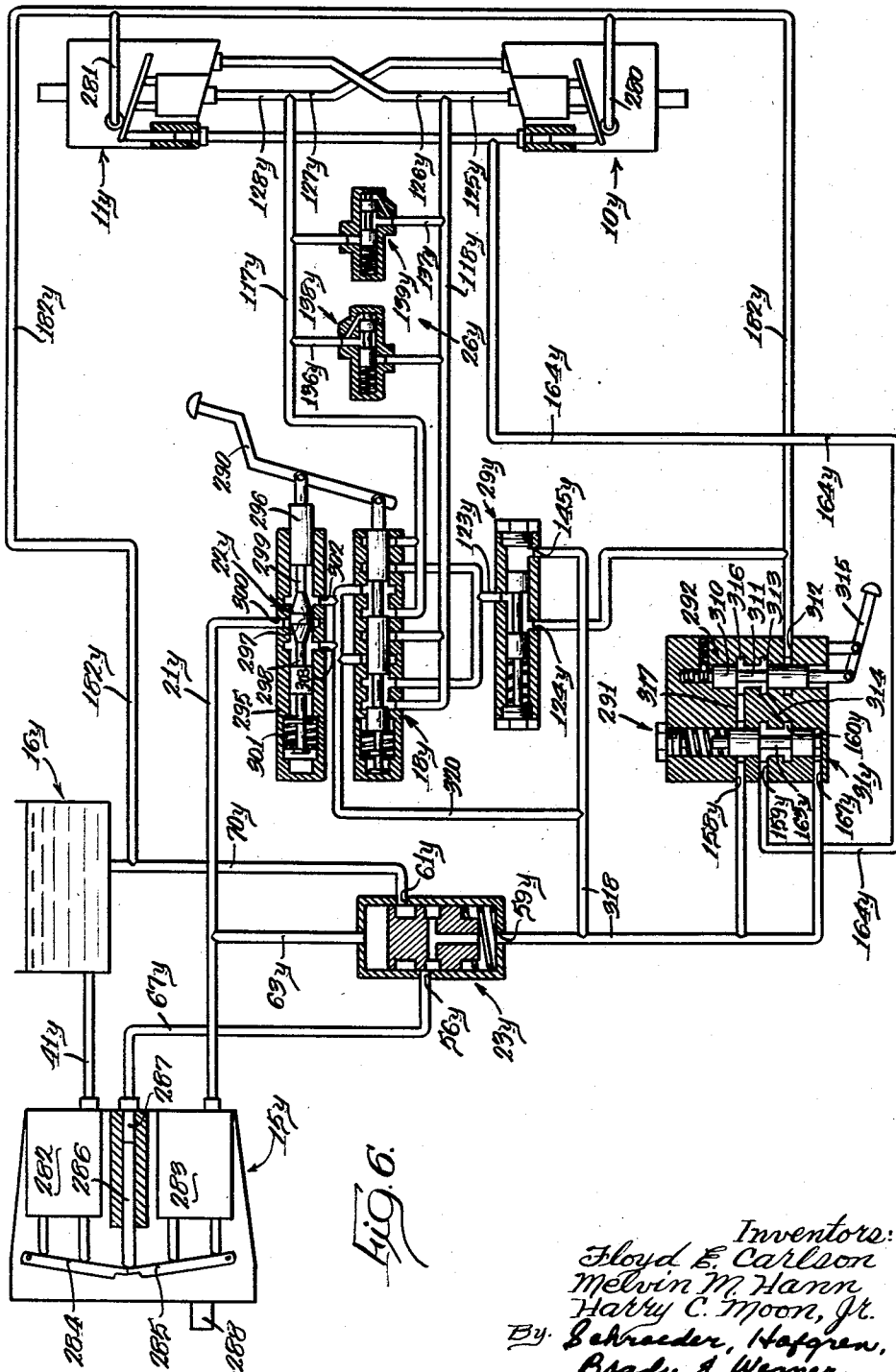
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HYDRAULIC TRANSMISSION

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This invention relates to hydraulic systems, and more particularly to hydraulic systems for mobile equipment of the slow moving, hard working types, such as lift trucks and the like.

It is a general object of the invention to provide a new and improved hydraulic system of the character described.

Vehicles of the type described, such as lift trucks, require drive means for propelling the vehicle, usually include a lifting device such as a lift fork, and require means for extending and retracting the lift fork, and means for raising and lowering the lift fork. Machines of this type require maneuverability in close quarters, precise and smooth operation, the ability to withstand high shock loads and overloads, and frequent speed changes and reversals.

With the above and other considerations in mind, it is a more specific object to provide a new and improved hydraulic system for propelling a vehicle such as a lift truck, for extending and retracting a lift device such as a lift fork, and for raising and lowering the lift device.

A further object of this invention is to provide a new and improved hydraulic system of the type described in the preceding paragraphs including one or more motors for propelling the vehicle, a reach motor for extending and retracting a lift device, a lift motor for raising and lowering the lift device, separately operable valves for the propelling, reach and lift motors respectively, connected in series circuit, and means providing a variable pressure, variable volume source of fluid for efficiently supplying fluid under pressure only at the rate and pressure required for a particular operation.

Another object is to provide a new and improved hydraulic system of the type described in the preceding paragraph including a variable speed, variable displacement pump, a prime mover for driving the pump, and a single control for controlling the speed of the prime mover, the displacement of the pump, and the operation of the propelling, reach and lift valves.

It is also an object of the invention to provide a new and improved variable pressure, variable volume hydraulic transmission for propelling a vehicle of the type described.

A further object is to provide a new and improved transmission of the type described in the preceding paragraph including a variable displacement pump, a propelling motor, a directional valve for controlling the flow of pressure fluid to the motor, and a single control for simultaneously operating the directional valve and varying the pump displacement.

Another object is to provide a new and improved hydraulic transmission system for propelling a vehicle of the type described including at least one propelling motor, means providing a source of operating fluid under pressure, directional valve means for controlling the flow of pressure fluid to the propelling motor, and valve means in the circuit with the propelling motor to restrict the

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flow of fluid from the motor to thereby provide braking of the motor.

Another object is to provide a new and improved transmission of the type described in the preceding paragraph including braking valve means for braking the propelling motor on slowdown of the vehicle and when the vehicle is parked on an incline.

A further object is to provide a new and improved transmission of the type described including means for braking the propelling motor at any time when the motor attains a speed requiring more flow than is delivered to the motor, as may occur when a downward incline is encountered while operating at full speed.

It is also an object to provide a new and improved hydraulic transmission for propelling a vehicle of the type described including a variable displacement propelling motor, and means responsive to the load imposed on the propelling motor for varying the displacement of the propelling motor to thereby vary the torque delivered by the motor in response to variations in the load on the motor.

A further object is to provide a new and improved hydraulic transmission for a lift truck or the like including a variable displacement propelling motor, and manually operable means for varying the displacement of the motor between a low speed, maximum torque value and a high speed, minimum torque value.

Other objects and advantages will become readily apparent from the following detailed description taken in connection with the accompanying drawings, in which:

Fig. 1 is a hydraulic circuit diagram illustrating a hydraulic transmission system for a lift truck or the like embodying the principles of the present invention, showing the various elements of the system in neutral or normal positions;

Fig. 2 is a hydraulic circuit diagram illustrating a modified hydraulic transmission system for a lift truck or the like embodying the principles of the present invention, showing the various elements in neutral or normal positions;

Fig. 3 is a view of the system shown in Fig. 2, with the directional valve, the variable orifice, the pump control valve, and the automatic braking valve shown in positions different from those illustrated in Fig. 2;

Fig. 4 is a fragmentary view of the system shown in Fig. 3, showing the automatic braking valve in a braking position;

Fig. 5 is another view of the system shown in Fig. 2, with the automatic torque valve, and the automatic prime mover control shown in positions different from those illustrated in Fig. 2; and

Fig. 6 is a hydraulic circuit diagram illustrating another modified hydraulic transmission system for a lift truck or the like embodying the principles of the present invention, with the various elements of the system positioned to effect reverse propelling of the lift truck at a low speed under control of the manually operable torque control valve.

While illustrative embodiments of the invention are shown in the drawings and will be described in detail herein, the invention is susceptible of embodiment in many different forms, and it should be understood that the present disclosure is to be considered as an exemplification of the principles of the invention and is not intended to limit the invention to the embodiments illustrated. The scope of the invention will be pointed out in the appended claims.

The hydraulic system illustrated herein is particularly adapted for use with mobile equipment of the slow moving, hard working type, such as lift trucks and the like. Lift trucks of the type referred to conventionally include thereon a movably mounted lift device, such as a lift

fork which is usually mounted for extension and retraction relative to the lift truck to reach and to withdraw from the load. The lift fork is also mounted for movement up and down on the lift truck to hoist and lower the load.

A typical truck of the type referred to includes a truck chassis or frame, a pair of driving wheels supported by one axle of the truck frame, usually near one end of the truck, one or more guiding wheels supported by the truck frame, usually near the other end of the truck, and means supporting the lift device on the truck frame for movement as described. The lift device may comprise a lift fork of generally L-shaped configuration including a generally upright leg and a generally horizontal leg, the latter disposed for movement underneath a load, such as a pallet conventionally employed in warehouses and the like for use in transporting stacked materials from place to place in the warehouses by lift trucks of the character described.

The hydraulic system in general

The hydraulic system illustrated is adapted to be mounted entirely on the truck frame of a lift truck or the like, and includes means for propelling the truck, means for extending and retracting the lift fork, and means for hoisting and lowering the fork. The system illustrated includes the advantages of a precise and smooth control of each operation provided, with an unlimited speed range for each operation, and with a wide variation in torque for the propelling operation. The system provides for extreme flexibility in installation.

Referring now to Fig. 1 particularly, as illustrated, the invention is embodied in a system which includes a pair of hydraulic motors 10 and 11 adapted for connection respectively with a pair of driving wheels of the lift truck for propelling the truck. The motors 10 and 11 are of a variable displacement type in order to provide a wide variation in developed torque, and are reversible in order that the truck may be driven either forwardly or reversely. A third hydraulic motor 13 of a constant displacement type is provided for extending and retracting the lift fork to reach and withdraw from a load, and a fourth hydraulic motor 14, of the reciprocable piston and cylinder type, is provided for lifting and lowering the lift fork.

The system includes means providing a source of operating fluid under pressure, comprising a variable displacement pump 15 connected to be supplied from a reservoir 16 and adapted to be driven by a variable speed prime mover 17, such as an internal combustion engine. The pump, the reservoir, and the prime mover are all adapted for mounting on the truck frame and for suitable connection in the hydraulic system. Similarly, the hydraulic motors 10, 11, 13 and 14 are also adapted for mounting on the truck frame, for suitable connection in the hydraulic system, and for connection with the devices which they operate.

Operations of the propelling motors 10 and 11, the reach motor 13, and the lift motor 14 are controlled respectively by 4-way directional valves, including a propelling valve 18, a reach valve 19, and a lift valve 20 which are connected in the system to control the flow of operating pressure fluid to and from the motors.

Operating fluid under pressure is supplied by the pump 15 to the body of the propelling valve 18 through a line 21a, 21b and 21c, and from the body of the propelling valve 18 to the body of the reach valve 19, and from the body of the reach valve 19 to the body of the lift valve 20. The valves 18, 19 and 20 are connected in series with the pump 15 and in series with each other. That is, when the valves are in neutral positions as illustrated in Fig. 1, fluid from the pump 15 flows through the valves to the next adjacent valve downstream. When one of the valves, the propelling valve 18 for example, is operated to direct fluid to the associated motor, fluid under

pressure from the pump 15 no longer flows to the next valve downstream. Instead, the fluid flow from the propelling motors is directed to the downstream valve. Fluid directed to the downstream valve in this manner may be utilized by suitable actuation of the downstream valve to effect operation of the associated motor. The respective motors are connected in series with the associated directional valve. The motors may be operated separately, or two or more of them may be operated simultaneously. While the directional valves have been illustrated as separate structures, it will be appreciated that these may all be made, if desired, in a single body, or the three may be separate and arranged in adjacent relationship in a multiple unit valve stack. The propelling motors 10 and 11 are connected in parallel with each other, and flow to these motors is normally equally divided between the two motors so that the power supplied thereto is the same.

Fluid under pressure flowing from the pump 15 passes through a member 22 providing an adjustable orifice for regulating the rate of flow to the directional valves. A pump displacement control valve 23 is responsive to the pressure drop across the adjustable orifice to vary the displacement of the pump 15 directly as the rate of flow through the orifice varies. An overpressure relief valve 24 is responsive to pressure downstream of the adjustable orifice and functions in response to the development of excessively high and dangerous system pressures to reduce the pump displacement to a minimum.

A single manually operable control, generally designated 25 is provided for controlling the operation of the directional valves 18, 19 and 20, and also for varying the size of the adjustable orifice and the speed of the prime mover 17.

The propelling valve 18 includes valving described more in detail hereinafter, manually controllable, for obstructing the flow of fluid from the propelling motors 10 and 11 thereby to brake the motors when the lift truck is slowed down to a stop or when the truck is parked in neutral on an incline. In order to facilitate the braking of the propelling motors, the circuit connected with these motors includes a braking relief valve means 26 which functions to maintain the braking pressure, and to establish a braking circuit returning braking fluid from the motor outlets to the motor inlets.

Also, the propelling motors circuit includes an automatic braking valve means 29 which functions to obstruct the flow of fluid from the propelling motors and thereby brake the motors at any time when the motors require a flow greater than that provided by the pump 15, as when the motors tend to overrun at a time when the truck is on a downward incline.

As previously noted, the propelling motors 10 and 11 are of the variable displacement type, and this characteristic is utilized to operate the motors either at a minimum displacement, high speed and low torque, or at a maximum displacement, low speed, and high torque. Operation of the motors in this fashion is controlled by an automatic torque valve means 31 for controlling the displacement of the motors.

System in detail

The pump 15 may be of a conventional construction including a rotatable cylinder block 35 suitably keyed to a pump drive shaft 36 for rotation therewith. The cylinder block is formed with an annular series of axially disposed cylinders which receive therein axially reciprocal pump pistons 38 which are biased outwardly of the cylinder block by springs not visible. The pistons 38, through the medium of suitable bearing shoe apparatus, bear against an adjustable angle swash plate 39 non-rotatably held in the pump housing 40. On rotation of the cylinder block 35, in a conventional manner the pump cylinders draw fluid from an inlet conduit 41 leading from the reservoir 16 and discharge fluid under pres-

sure into the pump outlet conduit 21a previously referred to. A drain conduit 42 leads from the interior of the pump housing 40 to conduct leakage fluid to the inlet line 41.

The variable angle swash plate 39 is normally biased to a minimum displacement position by means inherent in its mounting and by means of the spring biased pistons 38. Means is provided to vary the angle of the swash plate, and this means partakes of a displacement varying control piston 46 mounted in a control cylinder 47 in the pump housing to bear against the swash plate 39. When the control cylinder 47 is connected to drain, the swash plate 39 will assume a minimum displacement position. Control fluid under pressure may be admitted to the cylinder 47 to increase the swash plate angle and thereby increase the pump displacement.

The control valve means 23, previously referred to, is provided to control the flow of pressure fluid to and from the cylinder 47 in response to variations in the flow rate through the adjustable orifice in the member 22. The control valve 23 functions to effect an increase in pump displacement on increased flow through the orifice and to effect a decrease in pump displacement on decrease in the flow rate through the orifice.

The control valve 23 includes a valve body 51 which desirably may be integral with the pump housing end plate 15a. The valve body 51 is formed with a bore having a valve member 52 slidably positioned therein. The valve member 52 is biased by a spring 53 toward a position establishing communication between an outer groove 55 on the valve member and a valve port 56 in the valve body. Radial passages 57 formed in the valve member 52 communicate with the groove 55 and lead to an axial passage 58 in the valve member which opens to the lower end of the valve member to communicate with a valve inlet port 59. An outer annular groove 60 formed on the valve member 52 is provided to establish communication between the valve control port 56 and a drain port 61 when the valve member 52 is positioned as illustrated in Fig. 1.

Valve member 52 is sensitive to the pressure drop across the adjustable orifice in the member 22. Its upper end is exposed to pressure fluid ahead of the adjustable orifice by means of conduits 62 and 63 which lead from the pressure conduit 21a to the upper end of the valve body 51. The lower end of the valve member 52 is subjected to pressure fluid downstream of the adjustable orifice through the medium of conduits 64, 65 and 66, which lead from the pressure conduit 21c to the valve inlet port 59.

In operation, when the adjustable orifice is closed or substantially closed, there will be a pronounced pressure drop across the orifice, and the pressure of fluid in the lines 21a, 62 and 63 will be much greater than the pressure of fluid in the conduits 21b, 21c, 64, 65 and 66. As a result of this pressure differential, the greater pressure at the upper end of the valve member 52 will force the valve member downwardly against the bias of the spring 53 to substantially the position illustrated in Fig. 1. In this position of the valve member, the control cylinder 47 is connected to drain by means of a conduit 67 which leads from the control cylinder to the overpressure relief valve 24, the overpressure relief valve, a conduit 68, the port 56, the groove 60, and the drain port 61 which is connected by conduit 70 to the interior of the pump housing 40.

In the event the adjustable orifice is opened to permit an increased flow rate therethrough, the pressure drop across the orifice will be substantially reduced, the pressure acting against the lower end of the valve member 52 will be increased, and such pressure and the spring 53 will be effective to move the valve member 52 upwardly to a position establishing communication between the pressure conduit 66 and the control cylinder 47 through the axial passage 58, the radial passages 57, 75

groove 55, control port 56, conduit 68, relief valve 24, and conduit 67. The position of the valve member just described is not illustrated in connection with the circuit of Fig. 1, but is illustrated in the modified circuit of Fig. 3 wherein the control valve is designated 23x. In this position of the control valve, pressure fluid acting against the control piston 46 will be effective to increase the angle of the wobbler 39, thereby increasing the pump displacement in proportion to the flow rate through the adjustable orifice.

The overpressure relief valve 24 includes a valve body 72 which also may be formed integrally with the pump housing end plate 15a. The valve body 72 is formed with the bore having a valve member 73 slidably positioned therein and normally biased upwardly by a spring 74 to the position illustrated in Fig. 1 wherein an outer annular groove 75 formed on the valve member places the two conduits 67 and 68 in communication so that control over the control piston 46 is maintained by the control valve 23. The upper end of the valve member 73 is subjected to fluid under pressure from the conduit 21b. In the event that an excessively high and dangerous pressure is developed in the system, as may occur when a passage is improperly blocked or a part improperly jammed, such pressure functions to move the valve member 73 downwardly to a position (not illustrated) wherein an outer annular groove 76 on the valve member communicates with the conduit 67. When the valve member is thus positioned, the control cylinder 47 is connected to drain through the conduit 67, the groove 76, radial passages 77, an axial passage 78, and a conduit 79 leading to the drain conduit 70. The swash plate 39 is thereby allowed to return to a minimum displacement position to reduce the pump output until such time as the defective condition in the circuit is corrected.

The adjustable orifice in the member 22 is formed by means including a valve body 81 formed with a bore 82 having an inlet port 83 and an outlet port 84. The outlet port 84 forms an annular valve seat for cooperation with the conical end portion of a valve member 85 rotatable and slidable in the bore 82. The valve member 85 is formed with a threaded end portion 83 which is screwed into the valve body 81. Adjustment of the size of the orifice opening formed by the outlet port 84 and the conical end portion of the valve member is obtained by rotating the valve member 85 to screw the latter inwardly and outwardly relative to the outlet port 84. Rotation of the valve member 85 is effected by means of a rotatable shaft 86 mounted in a suitable bearing 87 and adapted to be rotated under control of the manually operable control 25.

The pump drive shaft 36 is connected to be driven by the prime mover 17 which may comprise an internal combustion engine of a conventional type having an output shaft 90 suitably connected to drive the pump shaft 36. The speed of the engine 17 is controlled by a fuel feed device such as a carburetor 91. The carburetor is controlled by a mechanism including a pivotally mounted lever 92 normally biased by a leaf spring 93 against an adjustable stop 94 so as to normally supply sufficient fuel to the engine 17 to sustain its operation at an idle speed.

The carburetor control lever 92 is connected to be automatically controlled with adjustments in the size of the orifice 22 by means of a link 95 pivotally connected at one end to the lever 92 and at its other end to an eccentric pin 96 on a disc 97 secured to the adjustment shaft 86 for rotation therewith.

In operation, when the adjustable valve member 85 is positioned as illustrated in Fig. 1 to substantially close the valve outlet 84, the eccentric pin 96 and the link 95 are positioned to adjust the carburetor to an idle speed. On rotation of the adjustment shaft 86 to increase the size of the orifice opening 22, the eccentric pin 96 is revolved about the axis of the shaft 86, moving the connecting link 95 to the left as viewed in Fig. 1,

to increase the fuel feed to the engine 17 and thereby increase the speed of the engine with increases in the flow rate through the adjustable orifice.

Rotation of the adjustment shaft 86 is effected by the single common control device 25 which is provided to effect operation of all manual controls included in the system. The control 25 includes a supporting bracket 100 having a centrally disposed hub portion 101 which supports a rotatable shaft 102. The shaft 102 is connected by a flexible shaft 103 to the adjustment shaft 86. The drive shaft 102, at its other end, supports an operating lever 104 universally connected with the drive shaft 102 at 105 and having a manually accessible hand grip portion 106 for pivoting the operating lever 104 in any direction from a neutral center position illustrated in Fig. 1 for purposes described more fully hereinafter. Also, however, the hand grip portion may be utilized to rotate the operating lever 104 about its axis, thereby to rotate the drive shaft 102 for effecting adjustment of the adjustable orifice in the member 22 and for varying the speed of the prime mover engine 17.

As previously noted, when the adjustable orifice is opened, operating fluid under pressure flows from the pump 15 to the propelling valve 18 through the pressure conduits 21a, 21b and 21c. The valve 18 is provided to control the propelling motors 10 and 11 and includes a valve body 110 having a longitudinal bore 111 which receives a valve stem 112 slidably mounted in the valve bore for movement in opposite directions from the neutral center position illustrated in Fig. 1.

The valve body 110 is formed with a pair of inlet ports 113 and 114, both communicating with the pressure conduit 21c and both adapted to communicate with the valve bore 111. The valve body 110 is also formed with a pair of motor ports 115 and 116 for delivering pressure fluid to conduits 117 and 118 respectively to obtain operation of the propelling motors 10 and 11 in reverse and forward directions. Motor ports 119 and 120 in the valve body communicate respectively with the conduits 117 and 118 for returning fluid from the propelling motors 10 and 11 when the motors are operated in forward and reverse directions. Drain ports 121 and 122 in the valve body 110 are both connected with a drain conduit 123 leading to the braking valve 29. The braking valve includes an outlet port 124 communicating with a pair of inlet ports to the downstream directional valve 19.

The propelling motors 10 and 11 are connected in series with the propelling valve 18 and in parallel with each other by means including the conduit 118 and branch conduits 125 and 126 which conduct operating fluid under pressure to the motors for operating the motors in a forward direction. The conduit 117 and branch conduits 127 and 128 conduct operating fluid under pressure to the motors for obtaining operation in a reverse direction. It will be understood that the circuits described, connecting the motors in parallel with each other provide for a differential action which permits relative movement between the motors as when the lift truck is turning with the wheel connected to one motor traveling in an arc of greater radius than the wheel connected to the other motor.

In operation, when the valve stem 112 of the valve 18 is positioned in the neutral center position as illustrated in Fig. 1, fluid flows from the conduit 21c to both valve inlet ports 113 and 114. From the inlet port 113, fluid flows through stem groove 129 to the drain port 121 and to drain conduit 123. From the inlet port 114, fluid flows through the stem groove 130 to the drain port 122 and to drain conduit 123.

In order to obtain operation of the propelling motors in a forward direction, the valve stem 112 is moved upwardly from the position illustrated in Fig. 1 to a position wherein the inlet port 113 is blocked by valve land 131. The entire flow from conduit 21c passes to the propelling motors through valve inlet port 114, stem groove 130, motor port 116 and conduit 118. Valve land 132 is positioned to block the motor return port 120 and the drain

port 122. When the valve is positioned as described, fluid flows from the motors 10 and 11 to drain through conduit 117, motor return port 119, stem groove 129, drain port 121, and drain conduit 123. The valve land 131 is positioned to block the motor port 115. The position of the valve just described is not illustrated.

In order to obtain operation of the propelling motors 10 and 11 in a reverse direction, the valve stem 112 is moved downwardly from the neutral center position illustrated in Fig. 1 to a position wherein the valve land 131 blocks the valve inlet port 114. The entire flow from the conduit 21c passes through the inlet port 113, stem groove 129, motor port 115, and conduit 117. The valve land 133 is positioned to block the motor return port 119 and the drain port 121. When the valve is positioned as described, return flow from the motors 10 and 11 passes through conduit 118, motor port 120, stem groove 130, drain port 122 and drain conduit 123. The motor port 116 is blocked by valve land 131. The position of the valve just described is not illustrated in Fig. 1, but is illustrated in the modified circuit of Fig. 6.

Movement of the valve stem 112 from the neutral center position illustrated to the positions described is effected by means to be described presently.

The manually controllable valve 18 for controlling operation of the propelling motors 10 and 11 includes valving for braking the propelling motors on slow down and in neutral. Principally, the valving referred to comprises the lands 131, 132 and 133 on the valve stem 112. When the valve stem 112 is positioned as illustrated in Fig. 1, the lands 131 and 133 are positioned to block the flow of fluid from the motor conduit 117, and the lands 131 and 133 are positioned to block the flow of fluid from the motor conduit 118. If the lift truck is parked on an incline, facing either forwardly or reversely, the weight of the truck and the load carried thereby will tend to cause the truck to roll down the ramp. Such condition causes the propelling motors 10 and 11 to function as pumps. But, inasmuch as both motor conduits 117 and 118 are blocked, the propelling motors, when rotated in either direction, pump against a blocked passage. Obviously, this restricts the flow of fluid from the motors, and brakes the motors.

The braking relief valve means 26, previously referred to in general, is provided to maintain the braking pressure in the motor return line 117 or 118, depending on the direction of truck movement. This valve means functions to bypass fluid from the motor return line to the motor inlet line to regulate the braking pressure in the return line and at the same time maintain hydraulic fluid in the braking circuit.

The braking relief valve means 26 includes a valve body 135 having a first conduit 136 connected to the motor conduit 117 and a second conduit 137 connected with the motor conduit 118. The valve body 135 is also provided with two valve bores, one bore housing a spring pressed check valve 138 biased to a closed position against the pressure of fluid in the conduit 136. The second bore houses a spring pressed check valve 139 biased to a closed position against the pressure of fluid in the conduit 137. Passages provided in the valve body enable the valve 138 to deliver fluid from the conduit 136 to the conduit 137 and additional passages enable the valve 139 to deliver fluid from the conduit 137 to the conduit 136.

In operation, assuming the truck is parked in neutral, as illustrated in Fig. 1, on an incline such that the truck tends to roll forwardly, the motors 10 and 11 tend to function as pumps, drawing fluid in through the motor conduit 118 and pumping the fluid out through the conduit 117. In this case, the valve lands in the valve 18 block the flow of fluid from the motors. The valve 138 is biased toward a closed position by its spring, and will thus maintain the braking pressure in the line 117 up to a predetermined value, at which time the valve will open.

When the valve opens, the motor outlet line 117 is connected to the motor inlet line 118 to thereby return fluid to the motor inlets. The valve 138 thus functions to regulate braking pressure and to provide a braking circuit and to maintain the braking circuit charged with fluid. The braking relief valve 139 functions in a similar manner when the truck tends to roll rearwardly and the propelling motors thus tend to pump out the conduit 118 and draw through the conduit 117. The setting of the valves 138 and 139 may be high enough so that they do not relieve the pressure of fluid for propelling the truck when the valve stem 112 is positioned for this purpose.

The automatic braking valve means 29, previously referred to in general, includes a valve body 141 having an inlet port connected with the drain conduit 123 and an outlet port 124 previously described. The valve body 141 is formed with a valve bore having a valve member 142 slidably disposed in the bore and formed with a central reduced portion 143 which serves to connect the valve inlet port 123 and the valve outlet port 124 when the valve member is positioned as illustrated in Fig. 1. A spring 144 acts against the valve member 142, biasing the valve toward a position in which communication is blocked between the inlet port 123 and the outlet port 124. At the opposite end of the valve member from the spring 144, the valve bore is provided with a pressure port 145 which is connected by a conduit 146 with the pressure conduit 64, and hence with conduit 21c, leading from the source of pressure fluid.

In operation, at any time when the pump 15 is pumping, and the adjustable orifice in member 22 is open, the pressure of fluid in the conduit 146 is sufficient to maintain the valve member 142 in a position as illustrated in Fig. 1, thereby placing the inlet port 123 and the outlet port 124 in communication. Thus, under normal operating conditions, when the propelling motors 10 and 11 are operated either forwardly or reversely, at either high speed or low speed, the return conduits from the motors are opened to drain since the valve member 142 is positioned to interconnect the drain ports 123 and 124.

If, under these conditions, the truck encounters a downward incline, the motors 10 and 11 may tend to overrun at a speed requiring more flow through the motors than is delivered by the pressure source. In this case, the motors begin to function as pumps, drawing fluid from the pressure conduit 21c and pumping through the drain port 123. Since the propelling motors are functioning as pumps and are requiring more fluid than that delivered by the pressure source, the pressure of fluid in the pressure conduits 21c and 146 drops, enabling the spring 144 to move the valve member 142 to a position blocking communication between the ports 123 and 124. Since the flow of fluid from the motors 10 and 11 is thereby restricted, the motors are braked down to a suitable speed, after which the pressure of the operating fluid will rise again to the proper value, again opening the braking valve 29. The braking position of the valve member 142 has not been illustrated in connection with the circuit of Fig. 1. However, the braking position of a similar braking valve is illustrated in Fig. 4 in connection with the illustration of the circuit of Figs. 2 through 5.

The propelling motors 10 and 11 may be similar and of conventional construction. Since the motors shown are identical, only motor 10 will be described in detail. Similar reference numerals are used to designate similar parts in the motor 11 with a prime suffix. The motor 10 includes a rotatable cylinder block 150 connected to drive the motor outlet shaft 151. The cylinder block 150 is formed with an annular series of cylinders housing reciprocal pistons 153 which bear against a variable angle swash plate 154. A control piston 155 is reciprocable in the motor housing to vary the angle of the swash plate 154.

The variable displacement characteristic of the propelling motors is utilized, in combination with the torque

multiplication valve means 31, previously referred to in general, to obtain the optimum usage of a small prime mover, enabling the reduction in over-all size of a lift truck or the like where maneuverability in close quarters is essential. With the hydraulic system illustrated, the optimum size prime mover, such as the engine 17, is one that will provide just enough power to maintain the vehicle at full speed with a full load on a level surface with no reserve power to climb an incline or ramp. The automatic torque multiplication valve 31 enables the practical use of a small prime mover engine by automatically sensing an overload condition on the motors 10 and 11 to automatically increase the displacement of the motors, thereby providing an increased torque output and a reduction of the speed of the motors.

As illustrated, the torque multiplication valve includes a valve body 157 having a pressure port 158, a control port 159 and a drain port 160. The valve body 157 is formed with a valve bore having a valve member 161 slidably positioned therein. The valve member is normally biased to the position illustrated in Fig. 1 by a spring 162, in which position an external annular stem groove or reduced portion 163 on the valve member connects the control port 159 and the drain port 160. When the valve member 161 is positioned as illustrated, the control pistons 155 for the motors 10 and 11 are connected to drain through the drain port 160, the stem groove 163, the control port 159, a conduit 164 leading from the control port 159, and branch conduits 165 and 166 which lead to the control pistons 155. The variable angle swash plates 154 for the motors 10 and 11 are thereby permitted to assume their normal minimum displacement angle for effecting operation of the motors at a high speed and a low torque.

The valve body 157 is formed with an additional port 167 connected by a conduit 168 to the pressure conduit 66. The valve member is thereby exposed to pressure fluid. In operation, the valve member 161 is normally positioned as illustrated in Fig. 1. In the event that the propelling motors 10 and 11 encounter an undue resistance to turning, as when the wheels driven thereby encounter an obstruction or an incline, the increased resistance to turning causes a pressure rise in the pressure conduits 66 and 168. The increased pressure causes movement of the valve member 161 to a position wherein the pressure port 158 and the control port 159 are connected through the reduced portion 163. Pressure fluid is thus supplied to the conduit 164 and branch conduits 165 and 166 to actuate the control pistons 155 and 155', shifting the swash plates 154 and 154' to an increased angle providing increased motor displacement, increased torque at the motors, and reduced speed. If the resistance of the motors 10 and 11 to turn decreases, there will be a pressure drop in the system which permits return of the valve member 161 to the position illustrated, thereby connecting the control pistons to drain. This permits return of the swash plates to minimum displacement angle. The shifted position of the torque multiplying valve member 161 referred to above is illustrated in Fig. 5, wherein the torque valve is generally designated 31x.

If desired, the circuit illustrated in Fig. 1 may incorporate a manually operable torque multiplication valve similar to that described in connection with the circuit illustrated in Fig. 6.

The directional valve 19 for controlling the flow of operating fluid to the reach motor 13 is substantially identical with the directional valve 18 for controlling the flow to the propelling motors 10 and 11. For this reason, the valve 19 will not be described in detail. The parts of the valve referred to in describing its operation have been given reference numbers similar to the corresponding parts of the valve 18, with a prime added.

The reach motor 13 may be of a conventional type including a rotatable cylinder block 170 connected to

drive an output shaft 171 and having axially reciprocal pistons 172 bearing against a swash plate 120 having a fixed angle for providing a constant piston displacement. The construction of the motor 13 is such that it may be operated forwardly or reversely by reversing the direction of fluid flow through the motor.

In operation, when the valve stem 112' of the directional valve 19 is positioned as illustrated in Fig. 1, fluid flows from the inlet ports 113' and 114' to the drain ports 121' and 122' through the stem grooves 129' and 130'. With the valve positioned as illustrated, the motor ports 115', 116', 119', and 120' are blocked by the valve lands 131', 132' and 133'.

Operation of the reach motor forwardly is obtained by moving the valve stem 112' upwardly from the neutral center position illustrated to a position in which the stem groove 130' connects the inlet port 114' to the motor pressure port 116' to deliver operating fluid through the conduit 118' to the reach motor inlet. Operation of the reach motor reversely may be obtained by moving the valve stem 112' downwardly from the position illustrated to a position in which the stem groove 129' connects the motor inlet 113' to the motor pressure port 115' to deliver operating fluid under pressure through the conduit 117' to the motor 13.

Movement of the valve stem 112' is effected by means to be described presently.

The directional valve 20 for controlling operation of the lift motor 14 is substantially identical with the valves 18 and 19 previously described. Accordingly, the valve 20 will not be described in detail. The parts of the valve referred to in describing its operation have been given reference numbers similar to those given to corresponding parts in the valves 18 and 19, except that a double prime suffix has been added.

The lift motor 14 may be of a conventional piston and cylinder type including a cylinder 175 having a piston 176 reciprocable therein and having a piston rod 177 adapted to be connected with the lift fork of the lift truck.

Fluid is admitted to the cylinder 175 to elevate the lift fork through motor pressure port 115'', a check valve 184, and a conduit 178 leading to a cylinder port 179. Fluid is exhausted from the cylinder 175 to lower the lift fork through the conduit 178 and the motor drain port 119''. The lowering of the lift fork may be accomplished at a rate controlled by an adjustable metering valve or the like 180 located in a drain conduit 181 leading from the drain port 121'' to a drain conduit 182 connected with the reservoir 16. A conduit 183 leads from the valve drain port 122'' to the drain conduit 182. Since operation of the lift motor 14 requires the flow of fluid to and from only one end of the cylinder 175, the motor ports 116'' and 120'' may be connected by a closed conduit or, if desired, plugged, or eliminated entirely.

In operation, when the valve member 112'' is positioned in the neutral center position as illustrated in Fig. 1, fluid enters the valve through the inlet ports 113'' and 114'', passes through the stem grooves 129'' and 130'', drain ports 121'' and 122'', conduits 181 and 183, and conduit 182 to the reservoir 16. With the valve stem positioned as illustrated, the motor ports 119'' and 115'' are blocked by the valve lands 133'' and 131'' so that the piston 176 is effectively held in position to hold a load.

In order to effect movement of the lift piston upwardly, the valve stem 112'' is moved downwardly from the position illustrated to a position in which the stem groove 129'' connects the inlet port 113'' with the motor pressure port 115''. In this position of the valve stem, the motor port 119'' is blocked by the valve land 133''. In order to permit movement of the lift piston 176 downwardly, the valve stem 112'' is moved upwardly from the position illustrated to a position in which the stem groove 129'' connects the motor return port 119'' to the drain port 121''. In this position of the valve stem, fluid flows from the cylinder 175 at a rate controlled by the adjust-

able valve 180 to control the rate at which the lift fork is lowered.

Movement of the valve stem 112' is effected by means which will be described now.

The valve stem 112 in the directional valve 18 is biased to the neutral center position illustrated in Fig. 1 by means of a spring 185. The spring bears against a lower collar 186 and an upper collar 187, both slidable on a reduced portion of the valve stem 112 in an enlarged portion of the valve body bore 111. The collars 186 and 187 are both adapted to bear against shoulders formed on the valve stem and in the valve bore in a manner to permit movement of the valve stem in opposite directions from the neutral center position shown to the two operative positions previously described. A collar 188 fixed on the reduced portion of the valve stem is engageable alternatively with the collar 186 or the collar 187 to limit movement of the valve stem 112 in opposite directions.

The valve stems 112' and 112'' of the directional valves 19 and 20 are normally biased to the neutral center positions illustrated by means identical with that described in connection with the valve stem 112.

Movement of the valve stem 112 in the directional valve 18 upwardly from the position illustrated in Fig. 1 is effected by the admission of pressure fluid to a cylinder 190 formed at the lower end of the valve body 110. Fluid under pressure is admitted to the cylinder 190 through a conduit 191 leading from the cylinder to a control valve 192. Movement of the valve stem 112 downwardly from the position illustrated in Fig. 1 is effected by admission of pressure fluid to a cylinder 193 formed in the upper end of the valve bore 111. Pressure fluid is admitted to the cylinder 193 through a conduit 194 from a control valve 195.

The pilot control valves 192 and 195 for controlling operation of the valve stem 112, together with similar pilot control valves 192' and 195' for controlling operation of the valve stem 112'' of the directional valve 20, all constitute a part of the master control unit 25, previously referred to.

In Fig. 1, for purposes of clarity in describing the operation of the master control unit 25, the unit has been illustrated twice in the figure. It appears once at the upper central portion of the figure, in elevation for illustrating the mechanical features of the unit previously described hereinabove. The master control 25 has been illustrated in Fig. 1 a second time at the upper right hand portion of the figure where the unit is shown in section, the section being taken through the pilot control valves 192 and 195 for illustrating the hydraulic features of the unit about to be described.

The stationarily mounted supporting bracket 100 of the control unit 25 includes four leg portions 197 which are angularly spaced about the axis of the drive shaft 102 and extend from the hub portion 101 axially and radially outwardly. The leg portions 197 provide supports for the valves 192, 195, 192' and 195', which are spaced at 90 degree intervals about the axis of the manually operable control member 104 when the latter is positioned in the neutral center position illustrated.

The pilot control valves 192, 195, 192' and 195' are all identical in construction. Hence, only the valve 192 will be described in detail; the construction of the remaining valves will be understood from the description of the valve 192.

The valve 192 includes a valve body 200 formed with a valve bore having a pressure port 201, motor port 202, and a drain passage 203 through the valve body intersecting the valve bore. The valve bore receives a slidably mounted valve stem 204 which is biased by a spring 209 to the position illustrated wherein a stem groove 205 connects the motor port 202 and the drain passage 203. Therefore, the cylinder 190 controlled by the valve 192 is connected to drain through the conduit 191, motor

port 202, stem groove 205, and drain passage 203. When the valve member 204 is positioned as illustrated, a reduced end portion 206 on the valve stem bears against the universally pivotable control lever 104.

In like manner, the similar valves 195, 192' and 195' are similarly positioned to connect the cylinders 193, 190', and 193' to drain. The drain passages of the four valves are interconnected as shown by a conduit 207 which in turn is connected to a conduit 208 leading to the drain passage 182.

Operating fluid under pressure is delivered to the pilot control valve pressure port 201 by means of a conduit 210 which leads from the pressure conduit 62, a connecting conduit 211, and a conduit 212. The pressure port of the valve 195 is supplied with pressure fluid through the conduit 210, and a connecting conduit 213 which leads to the pressure port of the valve 195.

Pressure fluid is supplied to the pressure port of the pilot valve 192' through the conduit 210 and a connecting conduit 214. Pressure fluid is supplied to the pressure port of the valve 195 through the conduits 210, 211, and a connecting conduit 215.

In operation, when the valves 192, 195, 192' and 195' are positioned as illustrated, the cylinders 190, 193, 190' and 193' are each connected to drain, and the control valve stems 112 and 112'' are biased by the springs 185 and 185'' to the neutral center positions illustrated.

In order to effect movement of the valve stem 112 upwardly from the position illustrated to the position previously described for obtaining forward operation of the propelling motors 10 and 11, the pilot valve 192 is actuated to conduct pressure fluid to the cylinder 190. Actuation of the pilot valve 192 is effected by pivotal movement of the control lever 104 upwardly from the position illustrated in Fig. 1 to move the pilot valve stem 204 from the position illustrated to a position in which the stem groove 205 connects the pressure port 201 and the motor port 202. When the stem 204 is moved to the position described, pressure fluid is delivered to the cylinder 190 through the conduit 191 to effect movement of the valve stem 112 upwardly.

In order to effect movement of the valve stem 112 downwardly from the position illustrated to the position previously described for obtaining operation of the propelling motors 10 and 11 reversely, the pilot valve 195 is actuated to admit pressure fluid to the cylinder 193. Actuation of the pilot valve 195 is effected by movement of the control lever 104 downwardly from the position illustrated to a position in which the pilot valve stem groove connects the pressure conduit 213 and the conduit 194.

In similar fashion, movement of the valve stem 112'' downwardly to the position previously described to effect movement of the lift piston 176 upwardly, is effected by actuation of the pilot valve 195', by the control lever 104 to connect the pressure conduit 215 and the conduit 194'. Movement of the valve stem 112'' upwardly from the position illustrated to the position described for lowering the lift piston 176 is effected by actuation of the pilot valve 192' by the control lever 104 to connect the pressure conduit 214 and conduit 191' for admitting pressure fluid to the cylinder 190''.

Thus, it will be seen that the control lever 104, in addition to providing an adjustment for the variable orifice 22 and an adjustment for varying the speed of the prime mover 17, also provides a single control for effecting operation of the directional valves 18 and 20. As explained, any one of the four pilot valves may be actuated by pivotal movement of the control lever 104 in the proper direction. Additionally, actuation of any two adjacent pilot valves may be effected simultaneously by moving the control lever 104 in an angular direction toward both adjacent pilot valves. More specifically, the control lever 104 may be moved upwardly and leftwardly at a 45 degree angle to actuate the valve 192 and

the valve 195', to simultaneously obtain forward propelling movement of the truck and hoisting movement of the lift device.

Movement of the valve stem 112' upwardly and downwardly from the neutral center position illustrated to the two positions previously described is effected by means of solenoids. A solenoid 217 is provided to move the valve stem 112' downwardly and the solenoid 218 is provided for moving the stem upwardly. The solenoid 217 is connected to ground and to a source of power represented at 219 by means of a wire 220 through a switching device 221 on the control lever 104 which includes a push button switch actuator 222 for energizing and deenergizing the solenoid. The solenoid 218 is connected to ground and to the source of power by a wire 223 through switching device 221 which also includes a push button switch actuator 224 for controlling energization of the solenoid 218. The switching device 221 including a push button switch actuator 222 and 224 may be of a conventional construction, and is mounted on the control lever 104 so as to permit control of the valve 19, as well as the other controls previously described, all from a single control device.

Modified circuit

The modified circuit of Figs. 2 through 5, like the circuit of Fig. 1, is a variable volume, variable pressure system.

A principal difference in the modified circuit resides in the provision of an adjustable flow rate orifice in the pump discharge line which is incorporated in the directional valve for controlling operation of the propelling motors. In the previously described circuit of Fig. 1 the adjustable orifice is completely separate and apart from the directional valves, and although adjustable by a control member also utilized to control operation of the directional valves, a separate movement of the control member is required to adjust the variable orifice differing from the movement of the control member to adjust the directional valves.

In the modified circuit of Figs. 2-5, wherein the adjustable orifice is made a part of the directional valve, the orifice opening and the directional valve opening are both controlled by a single valve member. Thus, as the directional valve is opened, the orifice is opened proportionately, to automatically increase the pump output in conformity with the position of the directional valve stem and control handle.

Also, in the modified circuit of Figs. 2-5, means is provided to vary the prime mover engine speed automatically in response to variations in the fluid pressure in the pump discharge line. In the system of Fig. 1, engine speed is controlled manually with adjustment of the variable orifice. With automatic control of the engine speed as in the circuit of Figs. 2-5, the speed varies with the load on the system.

Another important advantage in the system of Figs. 2-5 resides in the provision of makeup valve means and makeup porting in the directional valve stem which function when the directional valve is positioned in neutral to provide makeup fluid, replacing leakage, to maintain the braking circuit charged with fluid.

A principal advantage of a variable volume, variable pressure system of the type shown in all the drawings is that it provides a most efficient means of propelling a lift truck or the like, because the system provides operating fluid only at a rate and a pressure required for any given operating condition. While variable volume, variable pressure systems can be utilized for obtaining other functions than propelling, precise and independent control of the speed of several operations at once is difficult to obtain. The modified circuit of Figs. 2-5 advantageously includes only propelling motors, with no reach or lift motors for operating a lift fork or the like included in the system.

Thus, the modified circuit illustrated in Figs. 2 through 5 embodies principles similar to those incorporated in the system of Fig. 1, and also includes some features which differ from the system of Fig. 1. Elements of the modified system which correspond to the system of Fig. 1 have been given similar reference numbers with a suffix "x."

Generally, the system of Fig. 2 includes the variable displacement propelling motors 10x and 11x adapted to be connected to the driving wheels of a lift truck or the like, a variable displacement pump 15x for supplying operating fluid from a reservoir 16x, and connected to be driven by a prime mover 17x, all of which may be identical with the corresponding elements in the system of Fig. 1. The flow of operating fluid under pressure from the pump 15x through a delivery line 21x to the propelling motors is controlled by a directional valve 18x.

Operation of the variable displacement pump 15x is controlled by a displacement control valve 23x and an over pressure relief valve 24x which may be identical respectively in construction and operation with the control valve 23 and the over pressure relief valve 24 illustrated in Fig. 1.

As in Fig. 1, the directional valve 18x includes braking valving to restrict the flow of fluid from the propelling motors when the valve is positioned in neutral, as illustrated in Fig. 2. The system of Fig. 2 includes a braking relief valve 26x which may be identical with the braking relief valve means 26 in Fig. 1, for operation in conjunction with the braking valving referred to to maintain pressure on the braking circuit and to port braking fluid from the motor outlets to the motor inlets. The system of Fig. 2 includes automatic brake valve means 29x similar to the brake valve 29 in the system of Fig. 1, except that the stem groove 143x in Fig. 2 is tapered, as illustrated, to provide a gradual cut off at the port 123x.

The system of Fig. 2 includes an automatic torque multiplication valve 31x similar to the valve means 31 in Fig. 1, for controlling the displacement of the propelling motors 10x and 11x to automatically increase the torque output of the motors and vary their speed inversely in response to pressure rises in the system due to increased load on the motors. In the system of Fig. 2, the torque valve is subjected to pressure fluid at the port 167x ahead of the variable orifice 22x, instead of downstream from the orifice as in Fig. 1. This difference is of little significance, however, since the pressure above and below the variable orifice is substantially the same when the orifice is fully opened, and it is only when the orifice is opened that the torque valve is intended to function.

Before describing the operation of the system of Figs. 2-5, a description of the directional valve 18x will be given.

As seen in Fig. 2, the directional valve 18x includes a valve body 233 formed with a longitudinally extending valve bore 234 having a valve stem 235 slidable therein in opposite directions from the neutral center position illustrated in Fig. 2 to operative positions for obtaining operation of the propelling motors forwardly and reversely. The valve body 233 is formed with an inlet port 236 which is connected to the pressure conduit 21x and which opens into an internal annular inlet groove 237. Further, the valve body is formed with a pair of pressure ports 238 and 239 connected by a conduit 240 which may, if desired, be within the valve body 233. Motor ports 241 and 242 lead from the valve bore, the former connected with the motor conduit 118x for conducting fluid under pressure to the motors to obtain forward operation, and the latter connected to conduit 117x for conducting fluid under pressure to the motors for reverse operation. Drain ports 243 and 244 are connected by a drain conduit 245 which in turn leads to the inlet port 123x of the automatic braking valve 29x.

The valve stem 235 is formed with a centrally disposed land 247, spaced lands 248 and 249, and stem grooves

250, 251, 252, and 253. Movement of the valve stem 235 is obtained by means of a manually operable lever 255 pivotally mounted on the valve body and having a suitable pin and slot connection with the valve stem.

The variable orifice 22x is formed in the system of Fig. 2 by means incorporated in the directional valve 18x including the valve inlet groove 237 and the central valve land 247 which is tapered at opposite ends in order to obtain a gradual opening and closing of the orifice. When the valve stem 235 is positioned as illustrated in Fig. 2, the orifice 22x is completely closed, there is no flow to the propelling motors, and the pressure upstream from the orifice builds up to a value considerably greater than that in the conduit 240 downstream of the orifice, and the upstream pressure is sufficient to move the control valve 23x to the position illustrated in Fig. 2 wherein the valve connects the pump control conduit 67x to drain and the pump assumes a minimum displacement operation.

In the system of Fig. 2, braking on slow down and while the truck is parked in neutral on an incline occurs in much the same manner as in the system of Fig. 1. With the valve stem 235 in neutral, as illustrated in Fig. 2, the motor ports 241 and 242 are blocked by the valve lands 249 and 248 so that there is no flow to or from the motor. If the valve stem is moved to the neutral position from an operating position to slow the truck down to a stop, or if the truck is parked in neutral on an incline, the motors 10x and 11x will tend to turn and to function as pumps. However, as illustrated, the motors pump against the closed directional valve 18x, and the latter thus functions to brake the motors. On continued rotation of the motors, braking fluid is pumped through one of the braking relief valves 138x or 139x, depending on the direction of rotation, in the manner described in connection with the description of the system of Fig. 1. The braking relief valve means functions to maintain pressure on the braking fluid in the motor outlet lines, to relieve this pressure to the motor inlet lines, thereby providing a braking circuit and maintaining the circuit charged with fluid.

During the braking operation described, it may be necessary to charge the braking circuit with makeup fluid because of leakage which may tend to dissipate the braking fluid. To this end, makeup valve means 230 is provided to deliver makeup fluid from the pump delivery line to the braking circuit. The makeup valve means 230 comprises a valve body 260 having a pair of spring pressed ball check valves 261 and 262. Fluid is conducted to the check valves through a conduit 263. The check valve 261 delivers makeup fluid to a conduit 264 and thence to the motor conduit 117x. The makeup valve 262 delivers fluid to a conduit 265 and thence to the motor conduit 118x.

During braking, when the motors 10 and 11 are rotated forwardly, fluid is drawn in through the conduit 118x and discharged through the conduit 117x. Under these conditions, the pressure of fluid in the conduit 117x maintains the check valve 261 closed. In the event the braking circuit requires makeup fluid, the reduced pressure in the conduit 118x is sufficient to permit opening of the check valve 262 by the pressure of fluid in the conduit 263, to thereby deliver makeup fluid to the intake line 118x. During braking operation, when the motors 10x and 11x tend to rotate reversely, the check valve 262 will be held closed, and the check valve 261 will function to supply makeup fluid.

Makeup fluid is supplied to the makeup valve means 230 when the valve stem 235 is positioned in neutral through passages provided through the directional valve 18x. The makeup passages include the valve inlet port 236, the valve inlet groove 237, radial passages 266 in the valve stem 235, an axial passage 267 in the valve stem, radial passages 268 in the valve stem, and the conduit 263.

Forward operation of the propelling motors is obtained by movement of the valve stem 235 to the right from the neutral center position illustrated in Fig. 2 to the position illustrated in Fig. 3. When the valve stem is positioned

as illustrated in Fig. 3, the variable orifice 22x is opened to increase the rate of flow through the pump delivery line 21x. Fluid flows through the valve inlet port 236, the adjustable orifice 22x, stem groove 250, valve outlet port 238, conduit 240, valve port 239, stem groove 251, and motor port 241 to conduit 118x to obtain forward operation of the propelling motors.

At the same time, the pressure drop across the variable orifice 22x is reduced substantially, and the pressure of fluid in the conduit 240, through a conduit 270 is sufficient to cause movement of the pump displacement control valve 23x to the position illustrated in Fig. 3, wherein pressure fluid flows through the valve 23x, through the over pressure relief valve 24x and to the pump control conduit 67x to increase the pump displacement in direct proportion to the flow rate through the adjustable orifice.

Also, fluid under pressure in the conduit 240 flows into a conduit 271 to the upper end of the over pressure relief valve 24x so that in the event of an excessively high pressure rise in the system, the over pressure relief valve will operate as previously described to connect the control conduit 67x to drain conduit 79x and reduce the pump displacement.

Fluid under pressure from the conduit 240 also flows through the valve body 233 to a conduit 272 and the port 145x in the automatic braking valve 29x to effect movement of the valve member 142x from the position illustrated in Fig. 2 to the position illustrated in Fig. 3. In the latter position, the stem groove 143x connects the drain ports 123x and 124x to permit the flow of fluid from the propelling motors to drain.

When the directional valve 18x and the adjustable orifice 22x are opened widely as illustrated in Fig. 3, the propelling motors 10x and 11x are operated at full speed in a forward direction with the various parts of the system positioned as illustrated in Fig. 3.

In the event that the propelling motors tend to overrun at a speed requiring a greater flow than that provided by the pump, as, for example, when the lift truck encounters a downward incline, the pressure of fluid in the pump delivery line 21x will drop due to the pumping action of the motors. A similar pressure drop occurs in the conduit 272, permitting the spring 144x in the automatic braking valve 29x to return the valve member 142x toward the position illustrated in Fig. 4. In this position, the valve member 142x functions to block the flow of fluid from the propelling motors to drain, thereby braking the motors down to a proper speed. Consequently, pressure in the pump delivery line 21x rises again to open the braking valve 29x.

If, during operation with the parts positioned as illustrated in Fig. 3, the lift truck encounters an upward incline, or an obstruction which increases the resistance of the motors to turn, there will occur a consequent pressure rise in the pump delivery line 21x causing also a pressure rise at the pressure port 167x of the torque valve 31x. Such a pressure rise is effective to cause movement of the torque valve member 161x from the position illustrated in Fig. 3 to the position illustrated in Fig. 5. In the latter position, the drain port 160x is blocked, and the pressure port 158x is connected to the control port 159x, thus delivering pressure fluid through the conduit 164x to shift the control pistons and the swash plates in the propelling motors to a maximum displacement position providing a maximum torque output and a consequent reduction in speed. The motors therefore respond automatically to meet the increased resistance to turning.

At the same time, the speed of the prime mover 17x is also increased to meet the increased demand. The engine speed is automatically increased by the means 231 previously referred to in general. This means comprises a piston and cylinder device including a cylinder 275 having a piston 276 reciprocable therein. The piston rod is connected to the carburetor lever 92x. The piston is biased to a normal engine idle speed position by a spring 277. On the opposite side of the piston from the

spring, the cylinder 275 is connected to the pump delivery line 21x by the conduit 278. Thus, when the pressure rises in the pump delivery line, the piston is shifted against the bias of the spring to a position illustrated in Fig. 5 to increase the flow of fuel to the engine 17x thereby increasing the engine speed and pump speed to meet the increased demand. After the obstruction or the ramp encountered by the truck has been negotiated, pressure will drop in the pump delivery line 21x, and the parts returned to the position illustrated in Fig. 3.

A particular advantage provided by the system of Figs. 2-5 is derived by incorporating the adjustable orifice 22x in the directional valve 18x in a manner so that both are controlled by the single operator lever 255 to open and close the adjustable orifice and the directional valve at the same rate.

Modification of Fig. 6

The modified system illustrated in Fig. 6 is similar to those illustrated in Figs. 1 and 2 in that it incorporates an adjustable orifice for controlling the flow rate and a pump control for controlling the pump displacement in a manner to provide a variable volume, variable pressure system which functions to deliver fluid only at the pressure and flow rate required for a given operation. The system of Fig. 6 is similar to that of Fig. 2 in that it includes only propelling motors 10y and 11y for connection with the driving wheels of a lift truck or the like, without including motors for operating auxiliary equipment, though the latter could be included if desired.

The principal advantage in the system of Fig. 6 not provided in the other systems is embodied in the provision of a torque multiplying valve means including, in addition to an automatic torque valve, a manually operable torque valve which may be utilized to hold the propelling motors in maximum displacement, minimum speed operation to "inch" the vehicle along, thereby enabling exact speed control in close quarters regardless of the condition of surface traversed by the vehicle.

In describing Fig. 6, parts which correspond to similar parts in the system of Fig. 1 are designated by similar reference numbers with a suffix "y." The propelling motors 10y and 11y may be identical with the reversible, variable displacement propelling motors 10 and 11 in the system of Fig. 1. As illustrated in Fig. 6, the motor housings include drain conduits 280 and 281 respectively for conducting leakage fluid from the motor housings to the drain conduit 182y for return to the reservoir 16y.

Operating fluid under pressure is supplied to the motors by a pump means 15y which may, if desired, be identical with the variable speed, variable displacement pump 15 illustrated in Fig. 1. As illustrated, however, the pump means 15y of Fig. 6 takes the form of a double unit pump which includes a first pump section 282 and a second pump section 283. The double unit pump draws fluid from the reservoir 16y through a conduit 41y and delivers to a pump delivery conduit 21y. Pump 15y is of the variable displacement type in which the axially reciprocable pumping pistons are controlled by variable angle swash plates 284 and 285 respectively. The swash plates are normally disposed in minimum displacement positions and may be moved to increased displacement positions by a control piston 286 reciprocable in a cylinder 287 which may be connected to drain or to pressure fluid through a conduit 67y and a pump displacement control valve 23y which may be identical with the control valve 23 in the system of Fig. 1. The pump 283 is driven by a drive shaft 288 which may be connected with a prime mover similar to that illustrated at 17 in Fig. 1. The second pump section may be connected in a conventional manner to drive the first pump section 282.

Operating fluid under pressure passes from the pump delivery line 21y to a variable orifice 22y, thence to a directional valve 18y, and from there to the propelling motors. A principal distinction in the system of Fig. 6 over that of Figs. 1 and 2 resides in the means which

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forms the variable orifice 22y. The directional valve 18y in the system of Fig. 6 is identical in most respects with the directional valve 18 in the system of Fig. 1, and for this reason will not be described in detail. Operation of the directional valve 18y in the system of Fig. 6 is obtained in a manner different from that employed in Fig. 1 in the use of an operating lever 290 which is pivotally connected directly to the valve stem of the directional valve and also pivotally interconnected with the valve stem of the means forming the orifice 22y. Operation of these two valves will be described more in detail presently.

Control over the displacement of the pump 15y is exercised by the control valve 23y in a manner identical with the control exercised by the valve 23 in Fig. 1. If desired, an over pressure relief valve similar to that illustrated at 24 and 24' in Figs. 1 and 2 respectively may be utilized in a similar manner in the unit of Fig. 6.

The directional valve 18y for controlling the flow of operating fluid to and from the propelling motors 10y and 11y, being identical with the directional valve 18 in the system of Fig. 1, includes valving for braking the propelling motors on slow down to a stop and when the truck is parked on an incline in neutral. Accordingly, the system of Fig. 6 includes braking relief valve means 26y which is equivalent to the braking valve means 26 in the system of Fig. 1, and includes a braking relief valve 138y for relieving the pressure of braking fluid in the conduit 117y and a braking relief valve 139y for relieving the pressure of braking fluid in the conduit 118y.

Also, the system of Fig. 6 includes an automatic valve means 29y which is identical with the brake valve 29 in the system of Fig. 1.

The system of Fig. 6 incorporates an automatic torque multiplication valve 31y for controlling the displacement of the propelling motors which is identical in operation with the torque valve 31 in the system of Fig. 1. As illustrated in Fig. 6, however, the automatic torque valve is incorporated in a combined torque valve means 291 which also incorporates a manually controllable torque valve generally designated 292.

The variable orifice 22y in the system of Fig. 6 is formed by means including a valve body 295 which is formed with a valve bore having a slidable valve stem 296 formed with a centrally located valve land 297 and stem grooves 298 and 299 on opposite sides of the land. The land 297 is tapered at opposite ends and cooperates with a valve inlet groove 300 to form the variable orifice 22y. The valve stem 296 is normally biased by spring 301 to a neutral center position not illustrated wherein the valve land 297 completely blocks the flow of fluid through the inlet groove 300. The valve stem 296 is movable by operation of the control lever 290 which may be utilized to move the valve stem in opposite directions from the neutral center position to alternatively connect the inlet groove with an outlet port 302 through stem groove 299 or to connect the inlet groove 300 to an outlet port 303 through stem groove 298, the latter position being illustrated in Fig. 6. In either of the last described two positions of the valve stem 296, the variable orifice 22y may be opened by variable amounts to provide a variable flow rate through the orifice to the inlet ports of the directional valve 18y.

The springs provided for centering the valve stem 296 and the directional valve stem normally function to maintain the operating lever 290 in a substantially upright position not illustrated. The operating lever may be moved from the described neutral position to the right, as seen in Fig. 6, to the position illustrated to cause movement of the directional valve stem to a position for directing pressure fluid to the motor conduit 117y for operating the propelling motors reversely. In this case, the valve stem 296 moves to the right from the neutral center position, and the directional valve stem moves to the left from the neutral center position. Alternatively, the op-

erating lever 290 may be moved to the left from the neutral center position described to cause movement of the valve stem 296 to the left from its neutral center position and to cause movement of the directional valve stem to the right from its neutral center position to obtain the delivery of pressure fluid to the motor conduit 118y for driving the propelling motors forwardly. In either of the operative conditions described, the propelling valve may be fully opened, and the variable orifice partially or fully opened under control of a single suitable control, such as operating lever 290.

In Fig. 6, the valve stem 296 is positioned to open the orifice 22y only partly so as to obtain a partial flow rate to the motors 10 and 11 to obtain their operation at a low speed.

The manually controllable torque valve 292 includes a valve bore which receives a slidable valve stem 310 having a stem groove 311 normally positioned to connect drain port 312 and motor port 313, the latter being connected to the motor port 160y in the automatic torque valve by a passage 314 so that the control pistons of the propelling motors are connected to drain through stem groove 163y and drain port 159y to condition the propelling motors for minimum displacement. The valve stem 310 is movable to the position illustrated in Fig. 6 by an operating lever 315 in which position the stem groove 311 connects the motor port 313 to a pressure port 316. The pressure port 316 is connected by a passage 317 to a pressure port 158y in the automatic torque valve. Thus, when the manual torque valve stem is positioned as illustrated in Fig. 6, the control pistons of the propelling motors are connected to pressure fluid through the conduit 164y, stem groove 163y, passage 314, stem groove 311, passage 317, port 158y, and pressure conduits 318 and 320 to cause maximum displacement, low speed, maximum torque operation of the propelling motors under manual control.

The manually operable torque control valve 292 may be utilized to hold the variable displacement propelling motors in full displacement, providing the lowest speed and maximum torque at the truck wheels regardless of the load. This permits the vehicle to be "inched" along, and additionally to roll over an obstruction without a reduction in speed, the increased load being evident only in a rise in system pressure. Thus, the operator is enabled to maintain exact speed control in close quarters regardless of the condition of the floor or terrain he is traveling over.

We claim:

1. In a hydraulic system, at least one hydraulic motor adapted for connection with a propelling wheel of a vehicle, at least one additional hydraulic motor adapted for connection with auxiliary vehicle equipment, a variable displacement pump having a discharge line for delivering operating fluid under pressure to the motors, a variable speed prime mover for driving the pump, separate valves, one for controlling the flow of operating fluid to each motor, a single control member, means for interconnecting the control member with the valves, the pump and the prime mover for controlling the operation of both valves, for varying the displacement of the pump, and for varying the speed of the prime mover.

2. In a hydraulic system, at least one hydraulic motor adapted for connection with a propelling wheel of a vehicle, at least one additional hydraulic motor adapted for connection with auxiliary vehicle equipment, a variable displacement pump having a discharge line for delivering operating fluid under pressure to the motors, a variable speed prime mover for driving the pump, separate valves, one for controlling the flow of operating fluid to each motor, a single control member, and means for interconnecting the control member with the valves, the pump and the prime mover for effecting separate or simultaneous operation of the valves and for, either separately or simultaneously with valve operation, simultaneously vary-

ing the pump displacement and the speed of the prime mover.

3. In a hydraulic system, at least one hydraulic motor adapted for connection with a propelling wheel of a truck or the like, at least one hydraulic motor adapted for connection with auxiliary truck equipment, means providing a source of operating fluid under pressure, separate valves, one for controlling the flow of operating fluid to each motor, each valve comprising a slidable valve stem, fluid operable means for effecting movement of one valve stem, solenoid means for effecting movement of the other valve stem, control valve means for controlling the flow of pressure fluid to the fluid operable means, a manually operable control member for actuating the control valve means, and switch means on the control member connected in circuit with the solenoid means for effecting operation of latter.

4. In a hydraulic system, at least one hydraulic motor adapted for connection with a propelling wheel of a truck or the like, at least one hydraulic motor adapted for connection with auxiliary truck equipment, means providing a source of operating fluid under pressure, separate valves, one for controlling the flow of operating fluid to each motor, each valve comprising a slidable valve stem, separate fluid operable means, one for effecting movement of each valve stem, separate control valve means, one for controlling operation of each fluid operable means, and a manually operable control member for actuating the control valve means either separately or simultaneously.

5. In a hydraulic system, at least one hydraulic motor adapted for connection with a propelling wheel of a truck or the like, at least one hydraulic motor adapted for connection with auxiliary truck equipment, means providing a source of operating fluid under pressure, separate valves, one for controlling the flow of operating fluid to each motor, each valve comprising a slidable valve stem, separate fluid operable means, one for effecting movement of each valve stem, separate control valve means, one for controlling operation of each fluid operable means, and a manually operable control member movable in one direction for actuating one control valve means and movable in another direction for actuating the other control valve means.

6. In a hydraulic system, at least one first hydraulic motor adapted for connection with a propelling wheel of a truck or the like, a second hydraulic motor adapted for connection with a truck lift device or the like extending and retracting the lift device, a third hydraulic motor adapted for connection with a truck lift device raising and lowering the lift device, means providing a source of operating fluid under pressure, separate directional valves respectively for controlling the flow of operating fluid to the first, second and third motors, each of said valves comprising a movable valve stem, separate fluid operable means, one for effecting movement of each of two valve stems, solenoid means for effecting movement of the other valve stem, separate control valve means, one for controlling operation of each fluid operable means, a single manually operable control member for actuating both control valve means, and switch means on the control member connected in circuit with the solenoid means for effecting operation of the latter.

7. In a hydraulic system for a lift truck or the like, a reversible hydraulic motor, a pump for supplying operating fluid under pressure to the motor, a directional valve for controlling the flow of pressure fluid to the motor including a valve stem movable in opposite directions from a neutral center position to obtain operation of the motor in opposite direction, fluid operable means, one for effecting movement of the directional valve stem in each direction from the center position, control valves, one for admitting fluid under pressure to each fluid operable means, each control valve having a valve stem normally positioned to connect the associated fluid oper-

able means to drain and movable to a position connecting the associated fluid operable means to pressure fluid, an elongated manually operable control member pivotally mounted at one end for pivotal movement in one direction from a neutral center position to actuate one control valve stem and for pivotal movement in another direction from the neutral center position to actuate the other control valve stem.

8. In a hydraulic system for a lift truck or the like, a reversible hydraulic motor, a pump for supplying operating fluid under pressure to the motor, a variable speed prime mover for driving the pump, a directional valve for controlling the flow of pressure fluid to the motor including a valve stem movable in opposite directions from a neutral center position to obtain operation of the motor in opposite directions, fluid operable means, one for effecting movement of the directional valve stem in each direction from the center position, control valves, one for admitting fluid under pressure to each fluid operable means, each control valve normally positioned to connect the associated fluid operable means to drain and movable to a position connecting the associated fluid operable means to pressure fluid, an elongated manually operable control member pivotally mounted at one end for pivotal movement in one direction from a neutral center position to actuate one control valve stem and for pivotal movement in another direction from the neutral center position to actuate the other control valve stem, means mounting the control member for rotation manually about its elongated axis, and means connected to the control member for varying the speed of the prime mover on rotation of the control member.

9. In a hydraulic system for a lift truck or the like, a reversible hydraulic motor, a variable displacement pump for supplying operating fluid under pressure to the motor, a directional valve for controlling the flow of pressure fluid to the motor including a valve stem movable in opposite directions from a neutral center position to obtain operation of the motor in opposite directions, fluid operable means, one for effecting movement of the directional valve stem in each direction from the center position, control valves, one for admitting fluid under pressure to each fluid operable means, each control valve having a valve stem normally positioned to connect the associated fluid operable means to drain and movable to a position connecting the associated fluid operable means to pressure fluid, an elongated manually operable control member pivotally mounted at one end for pivotal movement in one direction from a neutral center position to actuate one control valve stem and for pivotal movement in another direction from the neutral center position to actuate the other control valve stem, means mounting the control member for rotation manually about its elongated axis, and means connected to the control member for varying the pump displacement on rotation of the control member.

10. In a hydraulic system for a lift truck or the like, a reversible hydraulic motor, a variable displacement pump for supplying operating fluid under pressure to the motor, a variable speed prime mover for driving the pump, a directional valve for controlling the flow of pressure fluid to the motor including a valve stem movable in opposite directions from a neutral center position to obtain operation of the motor in opposite directions, fluid operable means, one for effecting movement of the directional valve stem in each direction from the center position, control valves, one for admitting fluid under pressure to each fluid operable means, each control valve having a valve stem normally positioned to connect the associated fluid operable means to drain and movable to a position connecting the associated fluid operable means to pressure fluid, an elongated manually operable control member pivotally mounted at one end for pivotal movement in one direction from a neutral center

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position to actuate one control valve stem and for pivotal movement in another direction from the neutral center position to actuate the other control valve stem, means mounting the control member for rotation manually about its elongated axis, and means connected with the control member for varying the speed of the prime mover and for varying the pump displacement on rotation of the control member.

11. In a hydraulic system for a lift truck or the like, a pair of reversible hydraulic motors, a pump for supplying operating fluid under pressure to the motors, a pair of directional valves, one for controlling the flow of operating fluid to each motor, each valve including a directional valve stem movable in opposite direction from a neutral center position to obtain operation of the associated motor in opposite directions, fluid operable means, one for effecting movement of one directional valve stem in each of the opposite directions, control valves, one for admitting fluid under pressure to each fluid operable means, each control valve having a valve stem normally positioned to connect the associated fluid operable means to drain and movable to a position connecting the associated fluid operable means to pressure fluid, an elongated, manually operable control member pivotally mounted at one end for pivotal movement in one direction from a neutral center position to actuate one control valve stem and for pivotal movement in another direction from the neutral center position to actuate the other control valve stem, a pair of solenoids, one for effecting movement of the other directional valve stem in each of the opposite directions, and switch means on the manually operable control member connected in circuit with said solenoids and operable to energize either solenoid.

12. In a hydraulic system having a pair of directional valves, each including a directional valve member movable in opposite directions from a neutral center position, fluid operable means, one for effecting movement of each directional valve stem, a pair of control valve means, one for each fluid operable means, each control valve means comprising a pair of control valves, one for obtaining movement of the associated fluid operable means in each direction, each of said control valves including a control valve stem normally positioned to connect the associated fluid operable means to drain and movable to a position connecting the fluid operable means to pressure fluid, a manually operable control member universally mounted at one end for pivotal movement in any direction from a neutral center position, said control valves being arranged about the axis of the control member with the stems of the control valves spaced at ninety degree intervals and with the stems of each control valve means at diametrically opposite positions for actuation respectively on pivotal movement of the control member in opposite directions, the control member being movable in directions intermediate said opposite directions for effecting simultaneous actuation of any two adjacent control valve stems.

13. In a hydraulic system for a lift truck or the like, a hydraulic motor, a pump for supplying operating fluid under pressure to the motor, passage means connecting the motor inlet and the pump outlet, a valve in the passage means for controlling the rate of flow of pressure fluid from the pump to the motor, and means in fluid communication with the passage means for sensing the rate of flow therethrough and controlling the pump to vary the pump output with variations in the demand as determined by operation of the valve thereby to provide delivery of the fluid at the rate and pressure required for a given operating condition.

14. The combination of claim 13, wherein the means for controlling the pump comprises, means for varying the pump displacement, and including means interconnecting the sensing means and the displacement varying means to increase the pump displacement in response to

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increase in the flow rate and to decrease the pump displacement in response to decrease in the flow rate.

15. In a hydraulic system, a hydraulic motor adapted for connection with a propelling wheel of a truck or the like, a variable displacement pump for supplying operating fluid under pressure to the motor, passage means connecting the pump outlet to the motor inlet, a valve in the passage means for controlling the flow of pressure fluid from the pump to the motor, an orifice of variable size in the passage means between the pump and the motor, means for varying the size of the orifice opening to vary the rate of flow therethrough, means for varying the pump displacement, and means in fluid communication with the passage means for sensing the pressure drop across the orifice and controlling the displacement varying means to increase the pump displacement in response to decreases in pressure drop across the orifice and to increase the pump displacement in response to increases in pressure drop across the orifice.

16. The combination of claim 15, including a single control member for operating the valve for the motor and for varying the size of the orifice opening.

17. The combination of claim 15, including means for simultaneously opening the valve and increasing the size of the variable orifice opening.

18. In a hydraulic system, a hydraulic motor adapted for connection with a propelling wheel of a truck or the like, a variable displacement pump having a discharge line for supplying operating fluid under pressure from the pump to the motor, a directional valve for controlling the flow of pressure fluid from the pump to the motor, an orifice of variable size in the pump discharge line between the pump and the valve, means for varying the size of the orifice opening as the demand on the system varies, fluid operable means for varying the pump displacement, means normally biasing the displacement varying means to a minimum displacement position, a control valve for controlling the flow of fluid to and from the displacement varying means, said control valve being responsive to increases in pressure drop across the orifice to connect the displacement varying means to drain to thereby decrease pump displacement, and being responsive to decreases in pressure drop across the orifices to connect the displacement varying means to pressure fluid to thereby increase pump displacement.

19. The combination of claim 18, including an over pressure relief valve connected between said control valve and the displacement varying means normally positioned to permit the flow of fluid between the control valve and the displacement varying means, said over pressure relief valve being responsive to predetermined excessively high pressure in the pump discharge line between said orifice and the directional valve to connect the displacement varying means to drain.

20. In a hydraulic system, a hydraulic motor adapted for connection with a propelling wheel of a truck or the like, a variable displacement pump having a delivery line for supplying operating fluid under pressure, a directional valve for controlling the flow of pressure fluid from the delivery line to the motor, an orifice of adjustable size in the pump delivery line between the pump and the directional valve, means for varying the size of the adjustable orifice to vary the rate of flow from the pump to the valve, a common actuator for the directional valve and for the orifice adjusting means operable to open and close the directional valve to permit and prevent the flow of pressure fluid from the pump to the motor and operable to increase and decrease the orifice size to control the rate of flow to the directional valve, and means responsive to the pressure drop across the adjustable orifice to increase the pump displacement on decreases in said pressure drop when the orifice size is increased to increase the flow rate and to decrease the pump displacement on increases in said pressure drop when the orifice size is decreased to decrease the flow rate.

21. The combination of claim 20, including means for varying the displacement of the motor normally disposed in a minimum displacement, high speed, low torque position, and means for sensing the load on the motor to move the displacement varying means to increase the motor displacement to a low speed, high torque value in response to increases in the load on the motor.

22. The combination of claim 20, including fluid operable means for varying the displacement of the motor, normally disposed in a minimum displacement, high speed, low torque position, torque valve means normally positioned to connect the fluid operable motor displacement varying means to drain and operable to connect the fluid operable motor displacement varying means to pressure fluid to effect movement thereof to a maximum displacement, low speed, high torque position.

23. The combination of claim 22, wherein the torque valve means comprises a manually operable valve movable from a normal position to a position for delivering pressure fluid from the pump discharge line to the fluid operable motor displacement varying means, said torque valve being manually operable at will to increase or decrease the speed of the motor and simultaneously vary the torque output of the motor inversely.

24. The combination of claim 22, wherein the torque valve means comprises a valve normally biased to a position connecting the fluid operable motor displacement varying means to drain and responsive to increased pressure in the pump delivery line as a result of increased resistance of the motor to turn, to connect the displacement varying means to the pump delivery line to cause movement of the displacement varying means to a maximum displacement, low speed, high torque position.

25. The combination of claim 20, including braking valving on said directional valve positionable to restrict the flow of fluid from the motor when the directional valve is positioned to block the flow of fluid from the pump to the motor, thereby to brake the truck on slowdown and when parked on an incline.

26. The combination of claim 20, including a braking valve subjected to pressure fluid in the pump delivery line and positioned thereby to connect the motor outlet to drain, means biasing the braking valve to a position restricting the flow of fluid from the motor to drain, said braking valve being operable by said biasing means, upon a drop in pressure of fluid in the pump delivery line whenever the motor tends to overrun at a speed requiring more flow than that provided by the pump, to restrict the flow of fluid from the motor to brake the truck.

27. In a hydraulic system, a hydraulic motor adapted for connection with a propelling wheel of a truck or the like, a variable displacement pump having a delivery line for supplying operating fluid under pressure, a directional valve for controlling the flow of pressure fluid from the delivery line to the motor, fluid operable means for effecting operation of the directional valve, a control valve for controlling the operation of the fluid operable means, means forming an orifice of adjustable size in the pump delivery line between the pump and the directional valve including an annular valve seat and a needle valve member threadably mounted for adjustment relative to the annular valve seat to vary the size of the orifice to vary the rate of flow from the pump to the directional valve, a manually operable control member pivotally mounted at one end for pivotal movement to actuate said control valve, means mounting the control member for rotation manually about its axis, means connecting the control member and the needle valve member to adjust the latter relative to the annular valve seat on rotation of the control member, and means responsive to the pressure drop across the adjustable orifice to vary the pump displacement directly with variations in the flow rate through the orifice.

28. In a hydraulic system, a hydraulic motor adapted for connection with a propelling wheel of a truck or the

like, a variable displacement pump having a delivery line for supplying operating fluid under pressure, a directional valve for controlling the flow of pressure fluid from the delivery line to the motor, including a reciprocal directional valve movable in opposite directions from a neutral center position, means forming an adjustable orifice in the pump delivery line between the pump and the directional valve including a control valve member movable in opposite directions from a neutral center position for varying the size of the adjustable orifice to vary the rate of flow from the pump to the directional valve, a manually operable actuator pivotally connected to both valve members and pivotable in opposite directions from a neutral center position to move the directional valve member in opposite directions and to vary the size of the adjustable orifice, and means responsive to the pressure drop across the adjustable orifice to vary the pump displacement directly with variations in the flow rate through the orifice.

29. In a hydraulic system, a hydraulic motor adapted for connection with a propelling wheel of a truck or the like, a variable displacement pump having a delivery line for supplying operating fluid under pressure, directional valve means including a valve stem movable in opposite directions from a neutral center position and having valving thereon for controlling the flow of pressure fluid from the delivery line to the motor, means forming an orifice of adjustable size in the pump delivery line between the pump and said valving including additional valving on said stem movable with said stem for varying the size of the adjustable orifice to vary the rate of flow from the pump to the motor, means for effecting movement of the valve stem, and means responsive to the pressure drop across the adjustable orifice to vary the pump displacement directly with variations in the flow rate through the orifice.

30. In a hydraulic system, a hydraulic motor adapted for connection with a propelling wheel of a truck or the like, a hydraulic motor adapted for connection with auxiliary truck equipment, a pump for supplying operating fluid under pressure, a variable speed prime mover for driving the pump, separate valves one for controlling the flow of operating fluid to each motor, each valve having a movable valve member, separate fluid operable means one for effecting movement of each movable valve member, separate control valve means one for controlling operation of each fluid operable means, a pivoted control lever selectively movable in one direction for actuating one control valve means and in another direction for actuating the other control valve means, means mounting the control lever for rotation about its elongated axis, and means for varying the speed of the prime mover on rotation of the control member.

31. In a hydraulic system, a hydraulic motor adapted for connection with a propelling wheel of a truck or the like, a hydraulic motor adapted for connection with auxiliary truck equipment, a variable displacement pump for supplying operating fluid under pressure, separate valves one for controlling the flow of operating fluid to each motor, each valve having a movable valve member, separate fluid operable means one for effecting movement of each movable valve member, separate control valve means one for controlling operation of each fluid operable means, a pivoted control member selectively movable in one direction for actuating one control valve means and in another direction for actuating the other control valve means, means mounting the control member for rotation about its elongated axis, and means for varying the pump displacement on rotation of the control member.

32. In a hydraulic system, at least one hydraulic motor adapted for connection with a propelling wheel of a vehicle, at least one additional hydraulic motor adapted for connection with auxiliary vehicle equipment, a pump in fluid communication with the motors for delivering operating fluid under pressure thereto, a variable speed

prime mover for driving the pump, separate directional valves, one for controlling the flow of operating fluid to each motor, a single elongate control member mounted for universal pivotal movement and for rotation about its elongate axis separately or simultaneously, and means for interconnecting the control member with the valves and the prime mover for effecting operation of both valves either separately or simultaneously on pivotal movement of the member and for varying the speed of the prime mover on rotation of the member.

33. In a hydraulic system, at least one hydraulic motor adapted for connection with a propelling wheel of a vehicle, at least one additional hydraulic motor adapted for connection with auxiliary vehicle equipment, a variable displacement pump having a discharge line for delivering operating fluid under pressure to the motors, separate reversing directional valves, one for controlling the flow of operating fluid to each motor, a single control member mounted for universal pivotal movement and for rotation about its elongate axis separately or simultaneously, and means for interconnecting the control member with the valves and the pump for effecting operation of both valves either separately or simultaneously and in either direction on pivotal movement of the member and for varying the displacement of the pump on rotation of the member.

34. In a hydraulic system for mobile equipment, a hydraulic motor, a pump in fluid communication with the motor for delivering operating fluid under pressure thereto, a variable speed prime mover for driving the pump, a valve for controlling the flow of operating fluid to the motor, a single elongate control member mounted for rotary movement about its elongate axis and for pivotal movement separately or simultaneously about an axis transverse to the rotary axis, and means intercon-

necting the control member with the valve and the prime mover for effecting operation of the valve on one of said member movements and for varying the speed of the prime mover on the other of said movements.

35. In a hydraulic system for mobile equipment, a hydraulic motor, a variable displacement pump in fluid communication with the motor for supplying operating fluid under pressure thereto, a reversing directional valve for controlling the flow of operating fluid to the motor, and a single elongate control member mounted for rotary movement about its elongate axis and for pivotal movement separately or simultaneously about an axis transverse to the rotary axis, and means interconnecting the control member with the valve and the pump for effecting operation of the valve in either direction on one of said member movements and for varying the displacement of the pump on the other of said member movements.

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