Sept. 10, 1940. G. A. WAHLMARK 2,214,389

HYDRAULIC CIRCUIT

Filed April 9, 1936 4 Sheets-Sheet 1

Fig. 1.

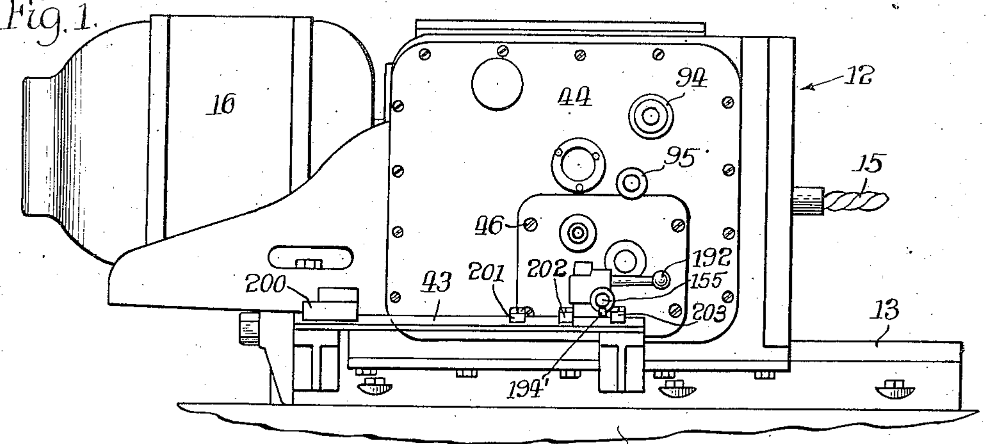


Fig. 2.

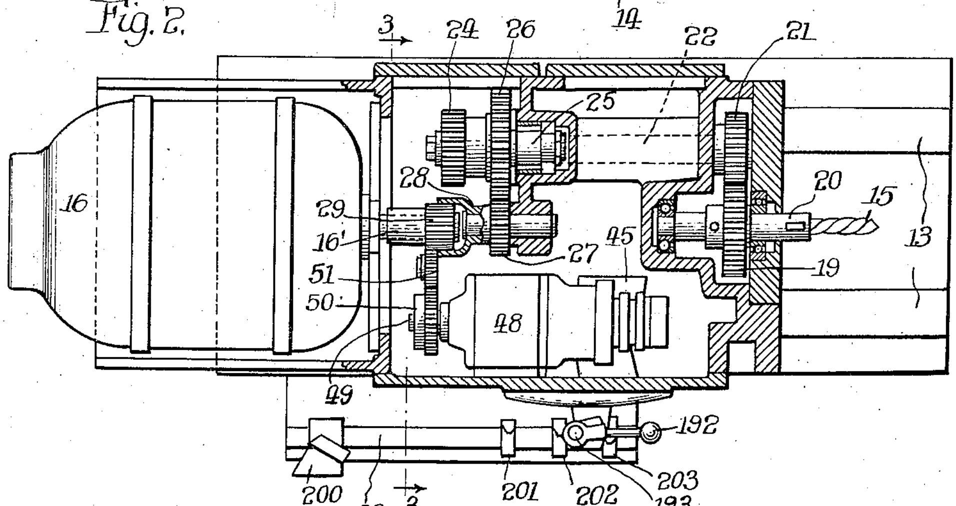
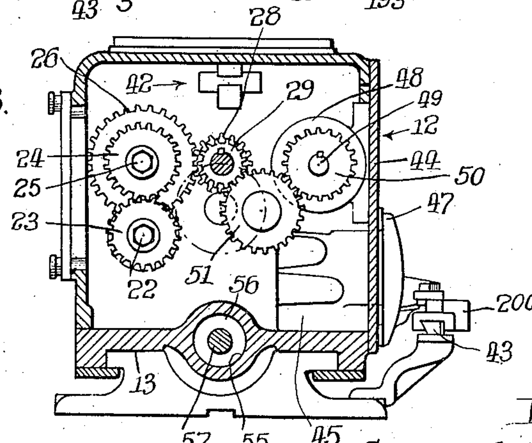


Fig. 3.



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HYDRAULIC CIRCUIT

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Fig. 4.

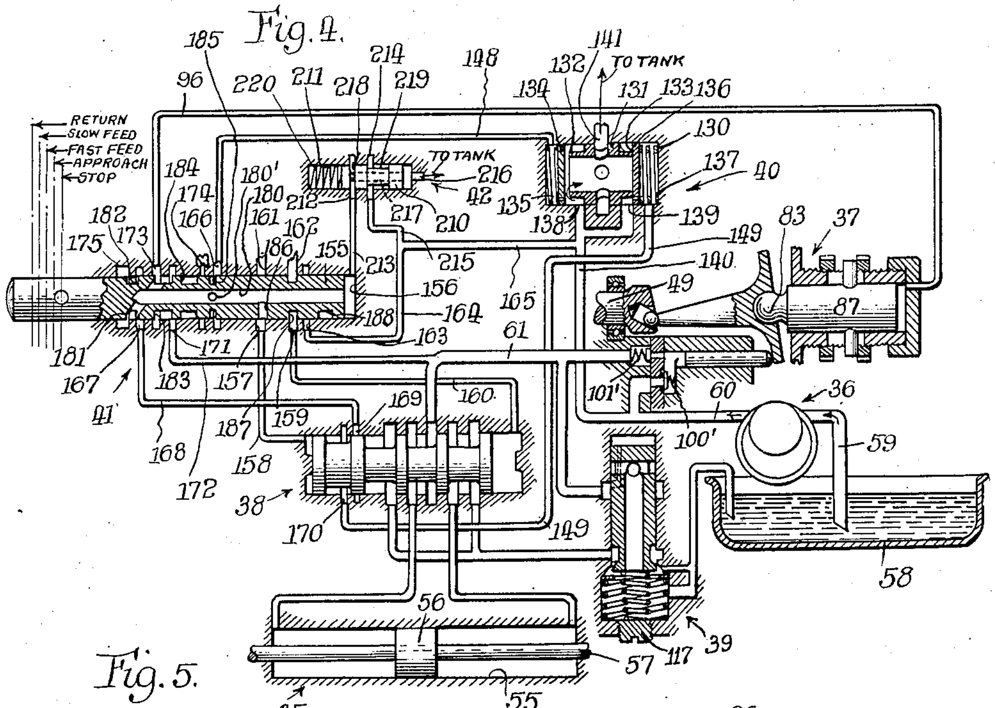
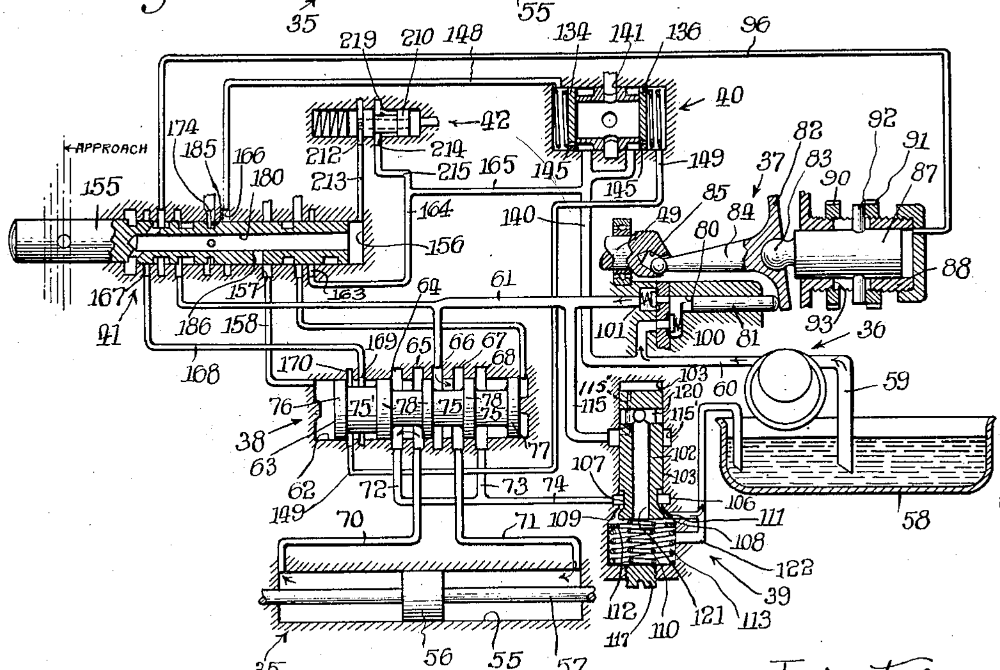


Fig. 5.



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HYDRAULIC CIRCUIT

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Fig. 6.

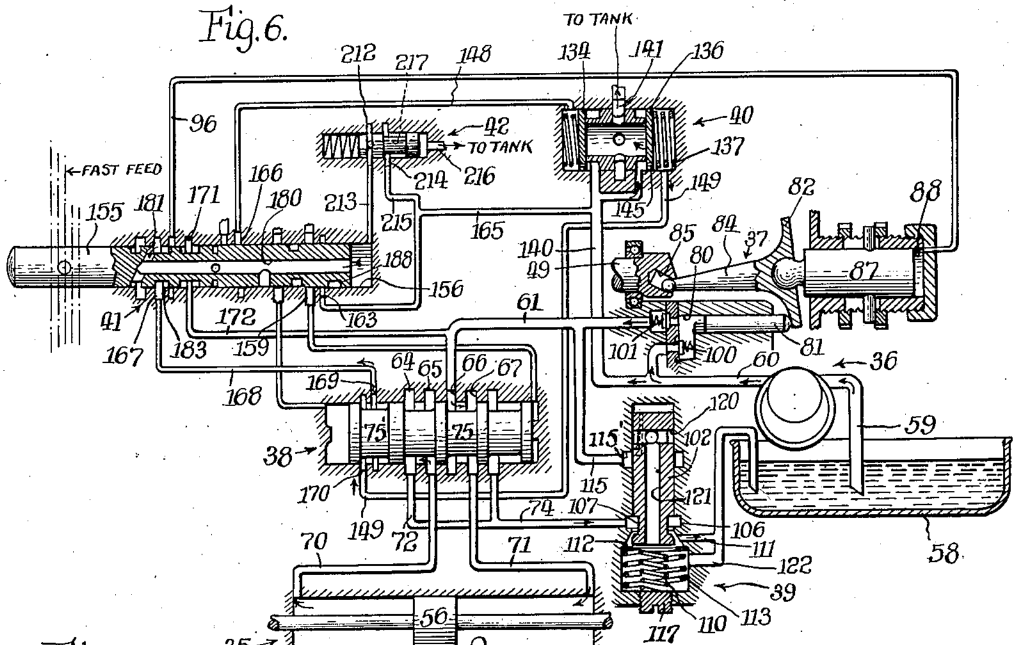


Fig. 7.

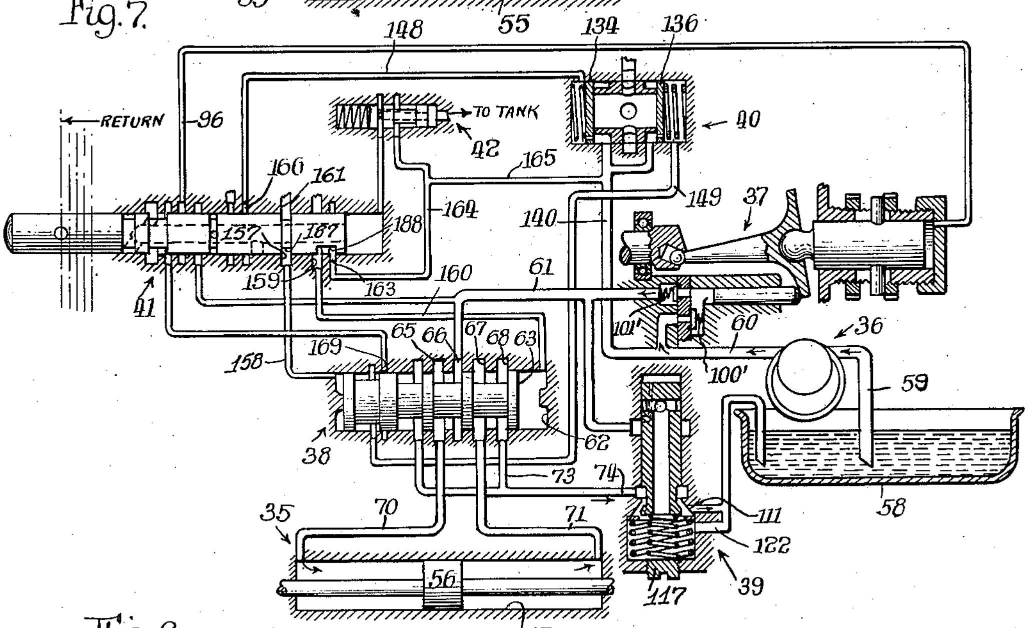
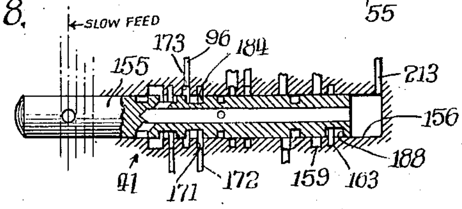


Fig. 8.



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HYDRAULIC CIRCUIT

Filed April 9, 1936 4 Sheets-Sheet 4

Fig. 10.

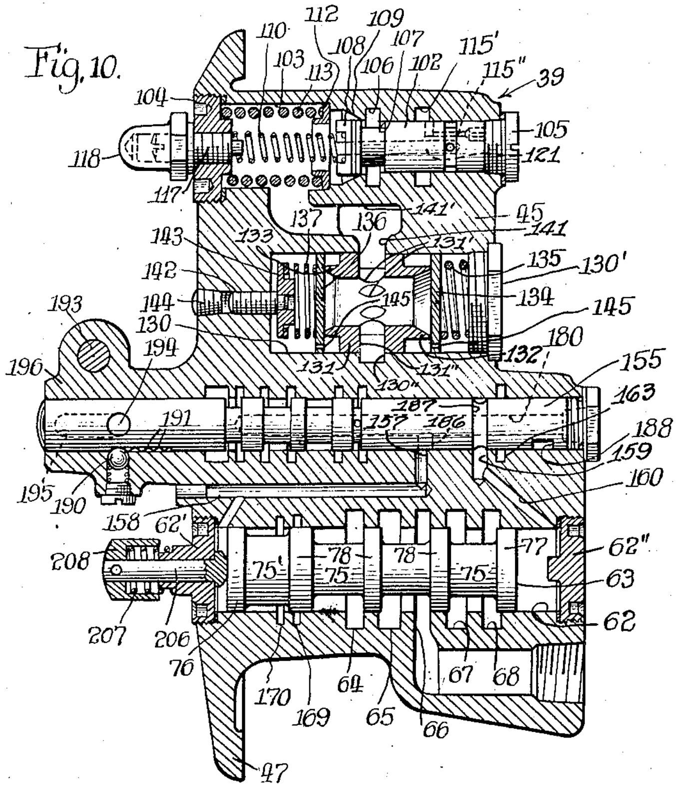


Fig. 12.

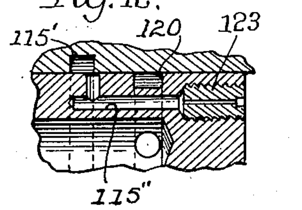


Fig. 11.

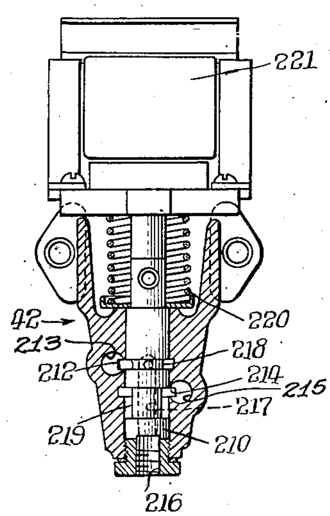
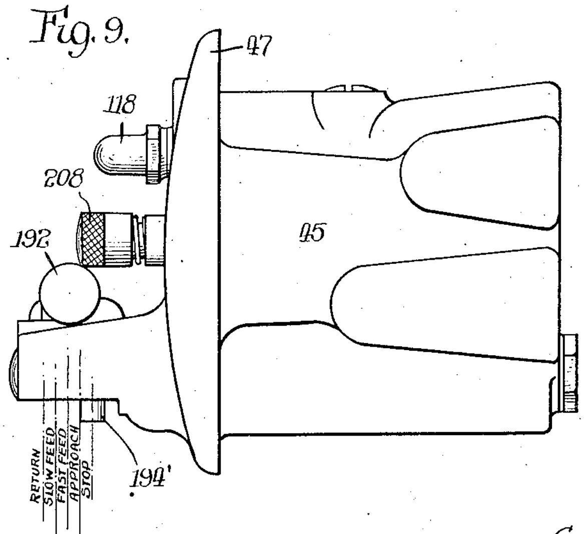


Fig. 9.



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Patented Sept. 10, 1940

2,214,389

UNITED STATES PATENT OFFICE

2,214,389

HYDRAULIC CIRCUIT

Gunnar A. Wahlmark, Rockford, Ill.

Application April 9, 1936, Serial No. 73,518

34 Claims. (Cl. 60—52)

The invention relates to a hydraulic circuit and has as a general object to provide a circuit having novel and improved means for supplying operating fluid to a hydraulic motor at selectively different rates for actuating a member at different speeds and under different loads.

A more particular object of the invention is to provide a hydraulic circuit having novel and improved means for supplying operating fluid to a reversible motor at relatively different rates and directions of flow for reciprocating a tool or work support of a machine tool at different speeds and under different loads.

Another object of the invention is to provide a hydraulic circuit, including a reversible hydraulic motor for actuating a tool or work support of a machine tool in either a forward or return direction, having novel and improved means for supplying operating fluid to the hydraulic motor in unmetered quantities and at a high rate to impart a shockless and high speed "traverse" movement to the support and for supplying operating fluid in accurately metered quantities and at a low rate to impart a smooth, slow or "feed" movement to the support.

Another object is to perfect a hydraulic circuit, including a hydraulic motor, having a continuously driven variable output pump capable of metering the quantity of fluid supplied to the motor or capable of permitting unmetered flow therethrough so that all fluid supplied to the motor may pass through the pump, and means including a source of fluid under pressure controllable to cause the pump to meter the fluid supplied to the motor, to permit unmetered flow to the motor or to permit no fluid to be supplied to the motor.

Yet another object is to provide a hydraulic circuit having a reversible hydraulic motor connected to a tool or work support to be driven, a large output pump supplying fluid to the motor at a high rate to impart a "traverse" movement to the support, a smaller output pump supplying fluid to the motor at a lower accurately metered rate to impart a "feed" movement to the support, and novel control means for and arrangement of the circuit whereby the support is driven through an automatic cycle of forward and return movement and at traverse or feed speeds but may, by manual actuation of the control means, be stopped, reversed or started forward again at any point in its cycle of operation.

Still another object is to provide a hydraulic circuit having a reversible hydraulic motor connected to a tool or work support to be driven, a large output pump supplying fluid to the motor at a high rate to impart a "traverse" movement to the support, a smaller positive displacement piston pump supplying fluid at a lower accurately metered rate to impart a "feed" movement to the support, the pumps being connected in series and driven continuously so that all fluid supplied to the motor passes through the piston pump, a reversing valve directing the fluid supplied to the motor to obtain movement of the support in a forward and return direction, a valve controlling the discharge of fluid from the motor to prevent the support from overrunning the fluid supply, a double bypass valve controlling the pressure of the fluid supplied by the large output pump having three adjustments rendering either the large output pump or the piston pump effective or both ineffective to supply fluid to the motor to obtain respectively "rapid traverse," "feed" or no movement of the support, and a pilot valve for coordinating the adjustments and positions of the bypass and reversing valves to obtain a predetermined cycle of movement of the support.

A further object is to provide a hydraulic circuit of the character described in which the large output pump and the piston pump are housed in a single casing and driven by a common shaft and in which the reversing, discharge control, bypass and pilot valves are all housed in a single casing thereby reducing to a minimum piping and couplings connecting the valves, pumps and motor.

Yet a further object is to provide in a hydraulic circuit including a pilot valve having "stop", "rapid approach," "feed" and "rapid return" positions, a remote control valve actuable to shift the pilot valve from "stop" to "rapid approach" and from "feed" to "rapid return."

Still a further object is to provide a hydraulic circuit having a hydraulic motor for actuating a tool or work support of a machine tool, pump means for supplying operating fluid to the motor, and a valve controlling the discharge of fluid from the motor so constructed and connected in circuit that during propulsion of the support by the tool, as in a climb cut, the pump means serves the dual function of metering the quantity of fluid supplied to the motor to determine the rate and of controlling the valve so that it permits escape of fluid from the motor only at the rate at which fluid is supplied independently of the pressure which may build up on the discharge side of the motor.

Still a further object is to provide a hydraulic circuit having a hydraulic motor for actuating a work support, a first pump for supplying fluid to the motor to drive the support at a rapid traverse rate, a second pump for supplying fluid to the motor to drive the support at a feed rate, the feed pump being manually adjustable to obtain a variety of feed rates and automatically adjustable to obtain either one of two preset rates without any by-passing of fluid, and control means for determining the rate at which the feed pump operates.

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

Fig. 1 is a front elevational view of a unit, sliding, drill head reciprocated by a hydraulic motor supplied with operating fluid by a hydraulic system embodying the features of the invention.

Fig. 2 is an irregular horizontal sectional view showing the gearing in the drill head of Fig. 1.

Fig. 3 is a transverse sectional view taken approximately along line 3—3 of Fig. 2.

Fig. 4 is a diagrammatic view of the hydraulic circuit with the elements shown in stop position.

Fig. 5 is a diagrammatic view of the hydraulic circuit with the elements shown in rapid approach position.

Fig. 6 is a diagrammatic view of the hydraulic circuit with the elements shown in fast feed position.

Fig. 7 is a diagrammatic view of the hydraulic circuit with the elements shown in rapid return position.

Fig. 8 is a view of the pilot valve of the hydraulic circuit shown in a position which it assumes for slow feed.

Fig. 9 is a side elevational view of the casing housing the reversing valve, discharge control valve, double bypass valve and the pilot valve of the hydraulic circuit.

Fig. 10 is a development of the valve casing showing the valves in axial section.

Fig. 11 is a detail view of a remote control valve of the hydraulic circuit.

Fig. 12 is an enlarged fragmentary section taken through the restricted passage of the discharge control valve.

While the invention is susceptible of various modifications and alternative constructions and while it may be embodied in a variety of structures, it is here shown and will hereinafter be described in a preferred construction in an exemplary embodiment, but it is not intended that the invention is to be limited thereby to the specific construction shown but it is intended to cover all modifications and alternative constructions falling within the spirit and scope of the invention as defined by the appended claims.

While a hydraulic circuit embodying the features of the invention might be employed in a variety of devices and through a hydraulic motor actuate a member at different speeds and through different cycles, the hydraulic circuit is, for purposes of disclosure, herein shown and will hereinafter be described as embodied in and actuating a unitary drill head 12. The drill head 12 is slidable longitudinally on ways 13 formed on the bed 14 of a machine tool and at one end carries a tool 15, a single drill being here shown, driven through suitable reduction gearing by an electric motor 16 mounted at the other end of the head. The reduction gearing (see Figs. 2 and 3) comprises a gear 19 fast on a driving spindle 20 receiving the drill, a gear 21 fast on one end of a shaft 22 extending longitudinally of the head, gear 23 fast on the other end of the shaft, gear 24 fast on one end of a stub shaft 25, gear 26 also fast on the stub shaft, and gear 27 rigid with a sleeve 28 received partially over a pinion 29 fast on the end of the shaft 16' of the motor 16.

Such a drill head is commonly reciprocated along the ways 13 at different speeds in either forward or return movement depending upon the character of the work to be performed by the tool carried on the end of the head. One such speed is a high speed during which the tool is brought up to the work and is commonly called "traverse" or "rapid approach." Another such speed is a substantially lower one during which the tool performs its operation. This speed must be maintained with a high degree of smoothness and uniformity as compared with "rapid approach" and is commonly known as "feed." The head is returned to normal position at a high speed comparable to "rapid approach" and is termed "traverse" or "rapid return." The head may also be arrested temporarily at some point other than its normal "stop" position which is known as "dwell." Movements of the head at these speeds may be arranged in any predetermined sequence to obtain the cycle of operation desired. Herein the head 12 has a cycle of operation comprising "rapid approach," "fast feed," "slow feed," "rapid return" and "stop."

To impart such a cycle of operation to the drill head 12, the hydraulic circuit herein comprises generally (Fig. 4) a reversible hydraulic motor 35, directly connected to the head, which is supplied with operating fluid, preferably oil, by a first pump 36 capable of a high output of fluid to impart a high speed or "traverse" movement to the head and by a second, positive displacement pump 37 of lower output supplying fluid at an accurately metered rate to impart a slow or "feed" movement to the head. Interposed between the pumps and the hydraulic motor is a reversing valve 38 directing the fluid supplied to the motor to obtain reversal thereof. In order to avoid uncontrolled movement of the head when the reaction of the tool on the work is such that it tends to advance the head, i. e., creates a negative work resistance, means generally designated 39 is provided for controlling the discharge of fluid from the motor and this means is made responsive only to the pressure of the fluid supplied to the motor and in that manner so controls the discharge of fluid as to prevent overrunning of the head. Control means is also provided for governing the rate at which fluid is supplied to the motor to obtain the various speeds of the head and has a first adjustment at which no fluid is supplied to the motor so that the head is at rest, a second adjustment at which fluid is supplied to the motor at a low accurately metered rate to obtain a "feed" of the head, and a third adjustment at which a large unmetered quantity of fluid is supplied to the motor at a high rate to obtain a "rapid traverse" of the head. Herein such control means comprises simply a double bypass valve 40 and obtains the different rates simply by control of the discharge pressure of the large output pump. The bypass valve 40 and the reversing valve 38 are controlled and coordinated by a pilot valve 41 to obtain the desired cycle of operation of the head 12. As here shown, the cycle of operation of the drill head 12 is initiated either by manual actuation of the pilot valve 41 or by actuation thereof through a remote control valve 42, the remainder of the cycle being controlled automatically through dogs (see Figs. 1 to 3) adjustably secured on a bar 43 extending longitudinally of the bed 14.

To reduce piping and couplings, the reversing valve 38, the discharge valve 39, the bypass valve 40 and the pilot valve 41 are all housed in a single casing 45 which is inserted through an aperture in the front panel 44 of the drill head and secured thereto by bolts 46 extending through a flange 47, formed at one end of the casing 45, and threaded into the drill head. The pump 36 and the pump 37 while indicated as separate units in the diagrammatic views, Figs. 4 to 7, are in reality also housed in a single casing 48 and are driven by a common shaft 49 as more particularly described and claimed in my copending application Serial No. 141,327, filed May 7, 1937. The casing 48 is mounted on the inside of the panel 44 and the pumps are continuously driven by the motor 16 through gear 50 fast on the common shaft 49 and idler gear 51 meshing with gear 50 and pinion 29 on motor shaft 16'.

The hydraulic motor 35 comprises a cylinder 55 and a piston 56 reciprocable therein. To facilitate the supply of operating fluid to the motor, the cylinder 55 herein is made rigid with and extends longitudinally of the drill head 12 while the piston 56 is fixed on a rod 57 which extends through both ends of the cylinder 55 and is secured to the bed 14 of the machine tool. As stated above, the motor 35 is supplied with operating fluid at a high unmetered rate by the pump 36 to impart a "rapid traverse" movement to the head 12 and with operating fluid at a lower accurately metered rate by the pump 37 to impart a slower or "feed" movement to the head 12. Both pumps supply fluid to the motor through a common supply conduit 61.

Interposed between the supply conduit 61 and the motor 35 is the reversing valve 38 formed by a cylindrical bore 62 in the valve casing 45 closed at its ends by caps 62' and 62'' (see Fig. 10) and in which is reciprocable a valve core 63. To direct the supply of fluid to the motor 35 in a manner to effect reciprocation thereof, the valve casing (Fig. 5) has opening into the bore 62 five annular, equally spaced ports 64, 65, 66, 67 and 68. Connected to the intermediate one 66 of these ports is the conduit 61 and leading from the port 65 to one end of the cylinder 55 is a conduit 70 and leading from the port 67 to the other end of the cylinder 55 is a conduit 71. The ports 64 and 68 are connected by branch conduits 72 and 73 to a common discharge conduit 74 which eventually leads to the tank or reservoir 58.

The valve core 63 is provided with three annular grooves 75 of substantially equal length and a fourth annular groove 75', of equal length but slightly shallower than grooves 75, forming a land 76 and a land 77 at the extreme ends of the core, and three intermediate lands 78. Each groove is of a length such that it is capable of embracing two ports. The core 63 has two positions and when shifted to the right or "advance" position (see Figs. 5 and 6) the supply port 66 and the port 67 are connected to supply operating fluid through the conduit 71 to impart movement to the head 12 in a direction to advance the same toward the work. In that position of the valve, ports 64 and 65 are connected to permit discharge of fluid from the other end of the cylinder through the conduit 70. When the valve core is shifted to the left or "return" position (see Figs. 4 and 7) supply port 66 is connected with port 65 and port 67 is connected with port 68 to effect movement of the head in a direction away from the work.

Movement of the head 12 toward or away from the work at a high speed requires no high degree of uniformity and the fluid for effecting such movement may be supplied by any pump capable of a large output at the required pressure. Herein the rapid traverse pump 36 is shown as a constant displacement variable pressure pump of the rotary type such as more particularly disclosed and claimed in my copending application Serial No. 675,218, filed June 10, 1933, issued Oct. 11, 1938 as Patent No. 2,132,813, and Serial No. 14,017, filed April 1, 1935, issued Feb. 7, 1939, as Patent No. 2,146,037. The pump 36 is continuously rotated by motor 16 and operates in well known manner to draw fluid, preferably oil, from the tank or reservoir 58 carried in the head, through an intake conduit 59 and to discharge the same to the hydraulic motor 35 through a passage formed in part by a conduit 60 and the conduit 61. With the entire output of the pump 36 supplied to the motor, the head 12 is rapid traversed in either a forward or return direction depending upon the position of the reversing valve 38.

When the tool is in engagement with the work, however, a slow, uniform movement of the head 12 is required and necessitates the supply to the motor 35 of a small quantity of fluid at an accurately metered rate. The means for supplying such a small accurately metered quantity of fluid is the pump 37 which herein takes the form of a variable displacement pump of novel construction more particularly described and claimed in my copending application Serial No. 141,327, filed May 7, 1937. This pump comprises one or more cylinders 80 having a piston 81 reciprocable therein and in all positions having one end projecting from the cylinder. The piston is actuated by a wobble plate 82 swiveled on a ball 83 and having an arm 84 projecting into a socket 85 formed in the end of the shaft 49 oblique to the axis thereof. The piston 81 merely abuts the wobble plate 82 and is not positively connected thereto so that the wobble plate is capable of imparting an exhaust stroke to the piston but is unable to impart a return or intake stroke thereto, thus making the pump non-self-priming.

The displacement of the pump 37 may be varied by changing the stroke of the piston 81 and this is accomplished by relative axial adjustment of the wobble plate 82 and the shaft 49. Such relative adjustment varies the extent to which the arm 84 is received in the oblique socket 85 thereby varying the throw of the wobble plate. Herein this is accomplished by movement of the wobble plate 82 and to that end the ball 83 upon which the plate is swivelled is formed on the end of a piston 87 slidable in a cylinder 88. The position of the piston 87 may be manually set at a predetermined displacement of the pump by means of rings 90 and 91 threaded onto the cylinder 88. To that end there is secured diametrically of the piston 87 a rod 92 projecting through longitudinal slots 93 in the cylinder 88 and between the rings 90 and 91. By rotation, these rings may be adjusted longitudinally of the cylinder 88 and thus secure the piston 87 in a position resulting in a predetermined displacement of the pump. The rings 90 and 91 have worm teeth formed on their periphery and may be rotated by worms having knobs 94 and 95 (Fig. 1) disposed outwardly of the drill head for convenient adjustment of the displacement of the pump. The displacement of the pump may also be varied automatically by supplying fluid pressure through a conduit 96 to the end of the cylinder 88. Under that condition the rings 90 and 91 are backed away from the rod 92 so as to permit movement of the piston under hydraulic pressure, the rings merely constituting stops limiting the extent of movement of the piston 87. Fluid pressure supplied to the cylinder 88 shifts the piston to reduce the displacement of the pump to the extent permitted by ring 90 while reaction of the piston 81 returns the piston 87 to normal position, determined by ring 91, when no fluid is supplied to cylinder 88. The manner in which the supply of fluid to the cylinder 88 is controlled will be described hereinafter.

The variable displacement pump 37 herein is connected in the hydraulic circuit in a novel manner facilitating and simplifying the control of the pumps to obtain the large quantity of fluid necessary to impart a "rapid traverse" movement to the head, the substantially smaller metered quantity of fluid necessary to impart a "feed" movement to the head, or to supply no fluid so as to bring the head to rest. The manner in which the variable displacement pump is connected in the circuit also simplifies the circuit and permits all operating conditions to be obtained with continued operation of both the constant displacement pump 36 and the variable displacement pump 37 which is desirable because of the greater accuracy and more immediate response obtained in the movements of the head than can be obtained by starting and stopping of the pumps. To that end each cylinder 80 of the pump is connected between the conduits 60 and 61 to form part of the passage leading from the constant displacement pump 36 to the motor. Each cylinder is provided with a first or intake check valve 100 permitting flow of fluid from the constant displacement pump into the cylinder 80 but preventing return flow and with a second or exhaust check valve 101 permitting flow from the cylinder 80 to the conduit 61 but likewise preventing return flow. Each of the check valves is yieldably urged to seated position by light springs 100' and 101', but the pressure at which the check valves open is not determined by the springs. The pressure at which intake valve 100 opens is determined by the force required to impart an intake stroke to the piston 81 and may, for example, approximate 50 pounds. The pressure at which exhaust valve 101 opens is determined by the pressure in conduit 61 and this pressure is maintained at a predetermined minimum but in excess of 50 pounds. This difference in the opening pressures of the check valves is essential in order that the variable displacement pump 37 may at times meter and limit the fluid supplied to the motor 35 and to effect a "feed" of the head 12.

Before describing the control means determining the rate at which fluid is supplied to the motor 35, the means for maintaining a minimum pressure in the conduit 61 will first be described. It is highly desirable in machine tools, especially during "feed" movement of the tool or work carrying support, that a uniform rate of movement be maintained. For example, it is essential to prevent a jump of the support when the tool reaches the end of its cut and the resistance offered by the cut is suddenly removed, or when the tool strikes a defect in the work piece, or when for any other reason the load on the motor driving the support is suddently varied and to prevent an overrunning of the support when the cut of the tool is such as to aid the motor. To that end means is provided which is operative, upon a breaking through of the tool or when the cut of the tool is such that it tends to advance the support, to control the discharge of fluid from the hydraulic motor 35 in a manner to resist and prevent such uncontrolled movement or overrunning of the support. This means is the valve 39 and is responsive solely to the pressure in the supply conduit 61.

The valve 39, shown diagrammatically in Figs. 4 to 7 and in section in Figs. 10 and 12, comprises a core 102 reciprocable in a bore 103 formed in the valve casing 45. One end of the bore is enlarged and is closed by a cap 104 threaded thereinto, while the smaller end is closed by a cap 105. Formed in the casing and opening into the bore is an annular port 106 with which the discharge conduit 74 leading from the reversing valve 38 communicates. The valve core 102 is formed with an annular groove 107 wider than the port 106 and normally disposed opposite the port. The land 108 formed by groove 107 at the end of the valve core is adapted to engage a conical seat 109 formed in the bore to control discharge from the port 106, and the valve core 102 is normally urged by a spring 110 in a direction to seat the land 108 and prevent discharge from the port 106. Movement of the valve core 102 in a direction opposed by the spring 110 permits discharge from the conduit 74 to the bore 103 and through a port 111 leading to the tank or reservoir 58. Such movement of the valve core 102 is normally limited by engagement of the valve core with an annular ring 112 yieldably supported in position by a compression spring 113 abutting cap 104.

Actuation of the valve 39 is dependent entirely upon the pressure of the fluid in the supply conduit 61 and to that end the upper end of the bore 103 is connected with the conduit 61 through a conduit 115, annular port 115' and a restricted passage 115'' in the valve core 102 (see Figs. 10 and 12). Thus only when the pressure of the fluid in the supply conduit 61 reaches a value determined by adjustment of the spring 110 is the valve core 102 forced downwardly to permit discharge from the conduit 74 and it is immaterial what proportion of the resistance to actuation of the motor 35, overcome by that pressure of the fluid in the supply conduit 61, is made up by the friction of the head 12 and by the load created by the cut of the tool, or by the restriction of the fluid discharged from the motor.

Good machine tool practice dictates that the ways in which a tool or work support reciprocates be sufficiently tight in order that accurate machining of the work may take place. As a result the friction of the ways as well as the friction of the fluid discharged from a motor actuating the support create a substantial resistance to movement of the support. This resistance herein is preferably made large and is utilized to prevent overrunning of the support at no load or under light cuts. Herein such resistance may be, for example, and preferably is, of a value such that it is overcome by a pressure of approximately one hundred pounds in the supply conduit to the motor.

With the support mounted so that the resistance to movement thereof under no load is overcome by a supply pressure of approximately one hundred pounds, spring 110 is adjusted so that valve 39 opens when subjected to a pressure slightly below one hundred pounds. As a result, the valve 39 permits unrestricted discharge from the motor under normal conditions during a cut creating a positive work resistance and during movement of the support under no load, but serves to restrict the discharge under abnormal conditions during such a positive cut, such as upon the breaking through of the tool, and during a cut creating a negative work resistance, such as a climb cut.

The operation of the valve may best be understood from the following examples: Assume first that the circuit is employed to actuate a support carrying a tool such as the drill 15 shown herein. As the tool is approached to the work, the resistance to movement of the slide at no load requires a pressure of one hundred pounds in the supply conduit 61 and thus valve core 102 is forced downwardly against the action of the spring 110 to permit unrestricted discharge through the conduit 74. As the tool engages the work, the pressure in conduit 61 rises so as to overcome the additional resistance caused by the cut of the tool and thus maintains valve 39 open to its full extent. When the tool breaks through and the flutes of the drill tend to advance the support and cause the same to jump forward, the pressure in conduit 61 immediately drops below one hundred pounds with the result that valve 39 closes and so restricts discharge of fluid from the motor that the support is prevented from jumping forward. For the second example, assume that the circuit is employed to move a work support past a milling cutter which is rotating in a direction to effect a climb cut. During the approach of the work to the tool as in the first example, the frictional resistance requires a pressure in conduit 61 of approximately one hundred pounds and thus opens valve 39 to permit unrestricted discharge of fluid. However, upon engagement of the tool with the work the tool tends to advance the support more rapidly than the fluid which is supplied to the motor. As a result the pressure in conduit 61 drops below one hundred pounds and spring 110 moves valve core 102 in a direction to restrict the discharge of fluid through the conduit 74. Such restriction of the discharge conduit causes a pressure to be built up in the discharge side of the motor which resists and prevents overrunning of the support. This resistance varies with, and is proportional to, the driving force acting on the support as a result of the reaction of the tool and the work. The motor is thereby retarded and the pressure in conduit 61 built up until it maintains valve 39 open to an extent that fluid is discharged therethrough only at the rate metered by the pump 37.

It will be apparent from the foregoing that the valve 39 is normally wide open and permits unrestricted discharge through the conduit 74 during movement of the support at no load and during normal operation with a positive cut but that it immediately and instantly comes into play to restrict discharge and prevent a jumping forward or an overrunning of the support when the tool breaks through or during a cut such that the reaction of the tool on the work tends to advance the support. As a result a unique circuit is provided in which during a cut creating a negative work resistance the pump means has the dual function of metering the quantity of fluid supplied to the motor to determine the rate of movement of the support and of controlling the valve 39 in a manner to maintain a resistance to movement which prevents overrunning of the support and permitting a discharge of fluid equal only to quantity supplied by the pump means. It will also be apparent that the pressure which may be built up in the discharge side of the motor is entirely independent of the strength of the spring 110. With this arrangement, the power required to drive the pumps for feeding the work is reduced to a minimum as no power is dissipated in overcoming a back-pressure.

While the spring 110 is here set at approximately 98 pounds to be overcome and thus maintain a pressure slightly in excess of 98, for example a pressure of approximately 100 pounds, this may be varied by adjustment of screw 117 against which one end of spring 110 abuts. The screw 117 is locked in adjusted position by a cap screw 118 (see Fig. 10). It will be apparent that the pressure for which the valve 39 is adjusted is also the minimum pressure at which the exhaust check valve 101 opens, pressures above the minimum being determined by the load.

In addition to functioning to maintain a uniform movement of the head 12 under all conditions, the valve 39 also acts as a safety valve limiting the maximum working pressure in the conduit 61. To that end the valve core 102 has an annular groove 120 communicating with an axial passage 121 discharging to the enlarged portion of the bore 103 with which communicates a conduit 122 leading to the reservoir 58. Under normal conditions of operation movement of the valve core 102 is not sufficient to cause groove 120 to register with port 115′ but, should the operating pressure in conduit 61 become excessive, the valve core 102 will be forced downwardly against the opposition of the spring 113 until groove 120 registers with port 115′. This permits unrestricted discharge from the supply conduit 61 through the valve 39 to the reservoir 58. The restricted passage 115″ (see Figs. 10 and 12) communicates with the port 115′ throughout the limit of movement permitted by the ring 112 and the restriction proper is provided by a drilled set screw 123 threaded into the passage. The restricted passage 115″ also serves to dampen the movement of the valve core 102 and the use of the set screw 123 makes possible a ready change of the restriction so that the valve may be adjusted to be immediately responsive yet not oscillate.

The means provided for controlling the supply of operating fluid to the motor 35 from the pumps 36 and 37, so as to obtain the desired movements of the head 12, takes the form of a double bypass valve 40 having a first adjustment at which a large quantity of fluid is supplied to the motor to "rapid traverse" the head, a second adjustment at which a smaller quantity of fluid is supplied to the motor at an accurately metered rate to obtain a "feed" movement of the head, and a third adjustment at which no fluid is supplied to the motor so that the head is at rest. This is all accomplished with continued operation of both the constant displacement pump 36 and the variable displacement pump 37.

The bypass valve 40 (see Figs. 4 and 10) comprises a cylindrical bore 130 in the valve casing 45 within which is disposed a cylindrical member 131 the intermediate portion of which is in fluid-tight relation to the bore 130 and the ends of which are of smaller diameter than the bore and form narrow annular valve seats 132 and 133. Slidable in one end of the bore 130 is a valve disk 134 urged to seat on the valve seat 132 by a light compression spring 135 abutting a cap 130' closing the bore. Slidable in the other end of the bore is a similar valve disk 136 urged to seat on the valve seat 133 by a heavy compression spring 137. The valve casing has an inlet port 138 opening into the bore between the intermediate portion of the member 131 and the valve disk 134 when seated and a similar port 139 opening between the intermediate portion 131 and the valve disk 136 when seated. These ports are connected by branch passages to a conduit 140 communicating with the conduit 60 at a point intermediate the constant displacement pump 36 and the variable displacement pump. Leading from the interior of the member 131 are a plurality of radial apertures 131' (see Fig. 10) opening to an annular groove 131'' formed in the intermediate portion of the member 131. The groove 131'' registers with an annular groove 130'', in the bore 130, which has a discharge port 141 leading to the reservoir 58. While the diagrammatic views (Figs. 4 to 8) would indicate separate return conduits from the valve 39 and the valve 40 to the reservoir, the valves actually discharge to a common passage 141' (see Fig. 10) and have a common return duct (not shown).

Spring 135 is capable of maintaining the disk 134 seated against low pressures in the conduit 140, for example, up to 5 pounds. Spring 137 is capable of maintaining disk 136 seated against a substantially higher pressure comparable with that required to open intake valve 100, namely 50 pounds, and this pressure furthermore may be varied by turning an adjusting screw 142 threaded into the valve casing. At the end projecting into the bore 130 the screw 142 carries a plate 143 against which the one end of the spring 137 abuts. The screw 142 is concealed by a plug 144. The valve disks are also adapted to be positively held seated so as to prevent all discharge of fluid through the port 141. To that end each valve disk is pierced by a small aperture 145 which permits leakage of fluid from the conduit 140 to the chambers formed behind the valve disks. Leading from the chamber formed behind the disk 134 is a conduit 148 and leading from the chamber formed behind the valve disk 136 is a conduit 149. These conduits may be closed, as will later be described, to prevent discharge of fluid from the chambers. Because, as is apparent from an inspection of the drawings, the area of the valve disks exposed to the pressure of the fluid in the conduit 140 when the disks are seated is substantially smaller than the area of the disks exposed to the fluid in the chambers formed behind the disks, either or both of the valve disks may be positively held seated by fluid pressure in the chambers by closing the conduits 148 or 149 or both.

When valve disks 134 and 136 are held positively seated by closing conduits 148 and 149, none of the fluid discharged by the constant displacement pump 36 is permitted to return to the reservoir 58 through the bypass valve 40. As a result, the pressure in the conduit 60 builds up until it is capable of opening both intake valve 100 and exhaust valve 101 of the variable displacement pump 37. All of the fluid displaced by the pump 36 is thus forced through the piston pump 37 to the conduit 61 and thence to motor 35 to impart a rapid traverse movement thereto. Because the constant displacement pump 36 is now operating at a pressure in excess of that maintained in the supply conduit 61 by the valve 39, the fluid displaced by the pump 36 flows through the variable displacement pump 37 without being metered even though the variable displacement pump continues to operate, the cylinder of the pump merely providing a passage for the flow of the fluid.

When conduit 149 is open but conduit 148 is closed, the bypass valve 40 maintains in the conduits 60 and 140 the pressure for which spring 137 is adjusted, for example 50 pounds. Such a pressure in the conduit 60 is capable of opening the intake check valve 100 and of imparting an intake stroke to piston 81 when the wobble plate 82 recedes, but is incapable of opening exhaust check valve 101 against the pressure in supply conduit 61. Under this condition the variable displacement pump 37 meters the quantity and boosts the pressure of the fluid supplied to the motor 35, and thus determines the "feed" movement of the head 12. The excess of fluid supplied by the constant displacement pump 36 over that metered by the variable displacement pump 37 builds up the pressure in conduit 140 slightly in excess of the 50 pounds for which the spring 137 is adjusted, and thereby unseats valve disk 136 and is returned through port 141 to the reservoir 58.

If conduit 148 is open the pressure in conduit 140 is determined by spring 135 which, as previously stated, maintains a pressure of approximately 5 pounds. Under this condition the fluid in conduit 60 is incapable of opening intake check valve 100 and all of the fluid supplied by the constant displacement pump flows through port 138 and thence through port 141 to be returned to the reservoir 58. Thus, though the constant displacement pump as well as the variable displacement pump continue to operate, no fluid is discharged to the motor 35 and consequently no movement is imparted to the head 12.

Pilot valve means 41 is provided for controlling and coordinating reversing valve 38 and bypass valve 40 so as to obtain the desired rate and direction of movement of the head 12. Herein the pilot valve comprises a cylindrical valve core 155 slidable longitudinally in a bore 156 in the valve casing 45. Opening into the bore 156 is a port 157 and leading therefrom is a conduit 158 communicating with one end of the bore 62 of reversing valve 38. A port 159 also opening into bore 156 has a conduit 160 leading therefrom which communicates with the opposite end of the bore 62 of the reversing valve 38. Disposed diametrically opposite port 157 is a port 161 leading to the reservoir 58, and diametrically opposite port 159 is a port 162 also leading to the reservoir 58. In close proximity to the ports 159 and 162 is an annular port 163 which is connected by conduits 164 and 165 to the conduit 140 leading to the bypass valve 40. An annular port 166 communicates with the conduit 148 leading to the chamber behind valve disk 134 and an annular port 167 has leading therefrom a conduit 168 communicating at the other end with an annular port 169 in reversing valve 38 and an adjacent annular port 170 in the reversing valve communicates with conduit 149 leading to the chamber formed behind valve disk 136. There are in addition an annular port 171 connected by a conduit 172 to the supply conduit 61, an annular port 173 into which conduit 96 opens, an annular port 174 leading to the reservoir 58, and an annular groove 175.

The valve core 155 (Fig. 4) has formed therein an axial passage 180, at one end opening through the core to the bore 156 and at the other end terminating in an oblique passage 181 communicating with a narrow annular groove 182 and a wide annular groove 183 axially spaced. Adjacent the annular groove 183 is a second wide annular groove 184 not in communication with the passage 180. Next is a narrow annular groove 185 which is in communication with the passage 180 through a port 180′, then a radial duct 186, an annular groove 187, not in communication with the passage 180, and a wide segmental groove 188.

For the cycle of operation to be imparted to the head 12, the valve 41 has five positions, as indicated in Fig. 4, namely, "stop," "approach," "fast feed," "slow feed" and "return." The various positions of the valve are indicated and the valve yieldably retained in those positions (see Fig. 10) by a spring pressed ball detent 190 engaging in notches 191 formed in the surface of the valve core. The valve may be shifted manually to its various positions by means of a lever 192 pivoted on a shaft 193 and engaging one end of a pin 194 fixed in the valve core 155 and projecting through longitudinal slots 195 in a tubular projection 196 of the valve casing. Automatic shifting of the valve is also provided for by the provision of dogs (see Figs. 1 to 3) suitably positioned on the bar 43 to engage the lower projecting end 194′ of the pin 194.

Four dogs 200, 201, 202 and 203 are here employed. Dog 201 engages the pin 194 to shift the pilot valve from "rapid approach" to "fast feed." Dog 202 shifts the valve from "fast feed" to "slow feed," and dog 203 shifts the valve from "slow feed" to "rapid return." Dog 200 shifts the valve from "rapid return" to "stop." The dogs of course are shiftable along the bar 43 so as to vary the point in the movement of the head 12 when the change in the rate of movement or the direction of movement takes place. It is believed obvious that the dogs might also be interchanged or more dogs employed to obtain a cycle different from the one here described.

The pilot valve 41 may be shifted to "rapid approach" position by direct manual actuation through the lever 192 or by means of the remote control valve 42. When the pilot valve is shifted by means of lever 192 the reversing valve 38 must also be shifted manually from its return position shown in Fig. 4 to its advance position shown in Fig. 5. To that end there projects through the left end cap 62′ of the reversing valve a plunger pin 206 normally held outwardly (Fig. 10) by a compression spring 207 bearing at one end against the cap and at the other end against a knob 208 fixed on the outer end of the pin. Pushing the pin 206 inwardly shifts the valve from the head return position shown in Figs. 4 and 10 to the head advance position shown in Figs. 5 and 6.

Remote control valve 42 comprises a valve core 210 slidable in a bore 211 which has an annular port 212 communicating by a conduit 213 with the bore 156 of the pilot valve, and an annular port 214 communicating by conduit 215 with the conduit 165. Leading from the right end of the bore, as viewed in Fig. 4, is a conduit 216 which discharges to the reservoir 58. The valve core 210 is provided with an axial passage 217 which communicates with the end of the bore 211 communicating with the conduit 216 and at its inner end communicates with an annular groove 218. The core has in addition a wide annular groove 219. The remote control valve is urged to and normally assumes the position shown in Fig. 4 by a compression spring 220 and may be shifted axially away from that position by any suitable means. Herein an electromagnet 221 is employed for that purpose.

When the remote control valve is in its normal position, shown in Fig. 4, it constitutes a return passage for the fluid discharged to the bore 156 of the pilot valve in certain positions thereof as will become apparent hereinafter. When the pilot valve 41 is in "stop" position, a shift of the core 210 of the remote control valve connects ports 214 and 212 to permit fluid from the conduit 140 to shift the pilot valve to "rapid approach" position and to shift the reversing valve from return position shown in Fig. 4 to advance position shown in Fig. 5. With the pilot valve in either the "fast feed" or "slow feed" position, a corresponding shift of the remote control valve to connect ports 214 and 212 shifts the pilot valve to "rapid return" position and returns reversing valve from its advance position shown in Fig. 5 to its return position shown in Figs. 4 and 7.

Having described the construction of the motor, the pumps and the valves, and having described the conduits or passages connecting the same, the operation and the course of the fluid through the hydraulic circuit may best be understood from the following description of the operation. Assume that the valves are in the positions shown in Fig. 4, particularly with the pilot valve 41 in "stop" position, but with motor 16 running to drive the drill, constant displacement pump 36 and variable displacement pump 37. Port 166, to which conduit 148 leading from the chamber behind valve disk 134 discharges, now communicates with groove 185 so that fluid may flow from the chamber behind the disk 134 through a radial port 180′ and axial passage 180 of the pilot valve, conduit 213, port 212, groove 218, and axial passage 217 of the remote control valve, and conduit 216 to the reservoir 58. Thus the bypass valve 40 maintains in the conduits 140 and 60 only a pressure determined by spring 135 which is approximately 5 pounds. This pressure is insufficient to open intake check valve 100. All of the fluid displaced by pump 36 is now bypassed by the bypass valve 40 and returned to the reservoir 58 through conduit 141 and no fluid is supplied to the motor 35 so that the head 12 is at rest.

To take care of any leakage past check valve 101 and any slight displacement of pump 37, there is a slight opening between port 171 (see Fig. 4) and groove 183 permitting return of the oil to the reservoir through conduit 213 and remote control valve 42.

To impart a "rapid approach" movement to the head 12 the pilot valve 41 is shifted one step to the left to the position shown in Fig. 5. This may be done manually through the lever 192 in which case the reversing valve 38 also is shifted manually by pressing the plunger pin 206 inwardly. Preferably, however, the pilot valve and the reversing valve are shifted hydraulically under the control of the remote control valve 42. By shifting the core 210 of the remote control valve to the left from its normal position shown in Fig. 4, groove 219 bridges ports 214 and 212 so that pressure fluid in conduit 140 may flow through conduit 165, conduit 215, ports 214 and 212, and conduit 213 to the bore 156 of the pilot valve. From the bore 156 the fluid flows through passage 180 through duct 186 and port 157 and then through conduit 158 to the left end of the bore 62 of the reversing valve 38 and shifts the same to the right to its "advance" position shown in Fig. 5, pressure fluid behind valve 63 being relieved through conduit 160, port 159, groove 187, and conduit 162. After having shifted the reversing valve 38 the fluid then acts upon core 155 of the pilot valve and shifts the same one step to the left to the position shown in Fig. 5. The fluid is prevented from shifting the pilot valve more than one step because in its "approach" position (see Fig. 5) the axial passage 180 through groove 185 communicates with port 174 which leads to the reservoir 58. Though conduit 96 is in communication with the passage 180 the low pressure fluid is incapable of shifting piston 87. After shift of the reversing valve 38 and the pilot valve, the remote control valve is returned to normal position by spring 220 when electromagnet 221 is deenergized.

This shift of the pilot valve to "approach" position closes port 166 and by preventing escape of fluid from the chamber behind valve disk 134 causes the valve disk to be positively seated by the pressure of the fluid flowing through the aperture 145 in the disk and trapped in the chamber behind the disk. Disk 136 likewise is held positively seated by the pressure of the fluid in the chamber behind the disk because port 167 also is closed and thus prevents discharge of fluid through conduit 149, reversing valve 38 and conduit 168. With all return of fluid to the reservoir 58 prevented, constant displacement pump 36 builds up a pressure in the conduit 60 which is sufficient to open exhaust check valve 101 as well as intake check valve 100 and all the fluid displaced by the constant displacement pump 36 flows through the variable displacement pump 37 to the supply conduit 61. From the conduit 61 the fluid passes through ports 66 and 67 in the reversing valve 38, now bridged by a groove 75, and then through conduit 71 to the right end of cylinder 55 of the hydraulic motor.

The fluid in the right end of cylinder 55 tends to move the same relative to the piston 56 and to force the fluid in the left end of the cylinder through conduit 70, ports 65 and 64 in the reversing valve, and conduits 72 and 74. Such discharge of fluid from the left end of cylinder 55 is, however, controlled by valve 39 the core of which is urged upwardly by spring 110 to engage valve seat 109 and thus prevent discharge from the conduit 74. The valve 39 is controlled solely by the pressure of the fluid in conduit 61 which is conducted to the bore 103 of valve 39 through a conduit 115. The pressure at which spring 110 is overcome may be varied by adjustment of screw 117, but with a pressure of 5 pounds maintained by the spring 135 and of 50 pounds maintained by the spring 137 of the bypass valve the pressure at which the spring 110 is overcome to permit flow from the conduit 74 may be considered, for example, to be approximately 100 pounds. The pressure of the fluid in conduit 61 necessary to overcome the resistance to movement of the slide at no load approximates 100 pounds and thus is sufficient to overcome spring 110 and force the core downwardly to unseat the land 108 and permit unrestricted discharge from the conduit 74 to bore 103 and thence to conduit 111 leading from the bore 103 to the reservoir 58. The valve thus permits a rapid approach movement of the head.

Just before the tool comes into contact with the work, the approach to feed dog 201 engages the lower projecting end 194' of pin 194 and shifts the pilot valve another step to the left of its "fast feed" position, shown in Fig. 6. With the pilot valve in this position, port 166 is still closed so that the valve disk 134 is positively retained seated. Port 167, however, now communicates with groove 183 in core 155 of the pilot valve and thence through passages 181 and 180, conduit 213, port 212 and axial passage 217 in the remote control valve, through conduit 216 to the reservoir. Thus fluid in the chamber behind valve disk 136 is free to escape through conduit 149, ports 170 and 169 of reversing valve 38 now bridged by groove 75', and conduit 168 to port 167 so that the valve disk is maintained seated only by the spring 137 which yields to permit bypass of fluid when the pressure in the conduit 140 exceeds 50 pounds.

With the pressure in the conduits 140 and 60 limited to 50 pounds, the fluid in the conduit 60 is capable of opening intake check valve 100 and of imparting a return or intake stroke to the piston 81, but is incapable of opening exhaust check valve 101 because there is at least the 100 pounds pressure determined by the valve 39 that must be overcome. However, the fluid which is forced into the cylinder 80 by the action of the constant displacement pump 36 and trapped therein by the check valve 100 is forced from the cylinder by the piston 81 through the exhaust check valve 101 and into the supply conduit 61 leading to the motor 35. From the conduit 61 the fluid passes through the reversing valve 38 and to the hydraulic motor 35, as previously described. Only the fluid displaced by the pump 37 is now supplied to the motor 35 and the quantity supplied is accurately metered and determined by the displacement of the pump 37. The rate of movement of the head 12 is thus determined by the displacement for which the variable displacement pump 37 is adjusted.

The friction of the head plus the load created by engagement of the tool with the work in a positive cut results in a total resistance requiring a pressure in excess of 100 pounds in the conduit 61 to overcome the same. Thus valve core 102 is maintained in open position as determined by engagement with annular ring 112. In this position there is unrestricted flow through the valve 39 so that no resistance is imparted by the valve 39 to movement of the motor 35 and head 12. However, should the tool break through, or should the tool be taking a cut which tends to advance the head, the pressure in conduit 61 would drop below 100 pounds, as described above, and spring 110 would immediately shift valve 39 to compensate for such variation by restricting flow from the conduit 74 and thus provide the resistance necessary to prevent a jump or an overrunning of the head. Thus the valve 39 serves in a unique manner to prevent jump of the head upon a lessening of the load such as a breaking through of the tool, and prevents overrunning of the head as a result of a negative cut.

The valve 39 also acts as a relief valve. Should the head strike an obstruction or should the cut of the tool be too deep so that the working pressure in the conduit 61 becomes excessive, the core 102 of the back-pressure valve would be forced downwardly in opposition to the spring 113 until groove 120 registers with port 115'. Fluid from the conduit 61 would then discharge through conduit 115, port 115', groove 120 and passage 121 to the enlarged portion of the bore

103 of valve 39 and thence through conduit 122 to the reservoir 58.

Upon continued movement of the head 12 at a "fast feed' rate, pin 194 strikes dog 202 and pilot valve 41 is thereby shifted to "slow feed" position shown in Fig. 8. In this position of the pilot valve, the bypass valve 40 and the reversing valve 38 remain in the position in which they were in Fig. 6, and pumps 36 and 37 continue to function in the same manner with pump 37 metering the fluid. Port 173 of the pilot valve, however, with which conduit 96 communicates is now connected through groove 184 with port 171 which is supplied through conduit 172 with high pressure fluid from supply conduit 61. The other end of conduit 96 discharges to cylinder 88 of pump 37 and the pressure fluid thus supplied shifts the piston 87 from the position shown in Fig. 6 to the left an extent permitted by the spacing of the rings 90 and 91. By such movement of the piston 87, the end of the arm 84 of the wobble plate 82 is forced into the oblique socket 85 of the shaft 49, thereby reducing the throw of the wobble plate 82 and correspondingly reducing the stroke of piston 81 and the displacement of the pump 37. A smaller quantity of metered fluid is now supplied by the pump 37 to the motor 35 and the head 12 has a correspondingly lower rate of movement.

Continued movement of the head 12 in a forward direction brings pin 194 into contact with the reversing dog 203 which shifts the pilot valve 41 another step to the left to its "return" position shown in Fig. 7. Ports 159 and 163 of pilot valve 41 are now bridged by the segmental groove 188 and fluid flows from conduit 140 through conduit 165, conduit 164, ports 163 and 159, and conduit 160 to the right end of bore 62 of the reversing valve 38, thereby forcing the valve core 63 to the left from the position shown in Fig. 6 to the position shown in Fig. 7, the pressure fluid at the other end of valve 63 being relieved through conduit 158, port 157, annular port 187, and port 161. Such shift of the reversing valve connects port 66 with port 65 so that fluid from the conduit 61 now flows through ports 66 and 65 and conduit 70 to the left end of cylinder 55, while the fluid in the right end of the cylinder 55 is discharged through conduit 71, ports 67 and 68, conduit 73 and conduit 74 through the back-pressure valve 39 as previously described. The shift of the reversing valve also closes port 169 thereby causing pressure to build up in the chamber behind valve disk 136, positively closing the same. Port 166 is still closed by the pilot valve thereby maintaining disk 134 positively seated so that the exhaust valve 40 now again prevents any return of fluid to the reservoir 58 and all of the fluid discharged by the constant displacement pump 36 is forced through the variable displacement pump 37 without being metered so as to impart a rapid traverse return movement to the head 12.

Should it be desirable to retard or delay the reversal of the head 12 so as to obtain a dwell, this may be accomplished by adjusting the dog 203 so as to effect only a partial shift of the pilot valve 41. Depending upon the extent of the partial shift of the pilot valve, a greater or lesser opening is obtained between the port 159 and the groove 188, thus determining the rate at which fluid is supplied to the right end of the reversing valve 38 and thereby determining the time required to shift the valve from its advance to its return position. As the valve is shifted it gradually closes ports 65 and 67, brings head 12 to a gradual stop, retains both ports closed for a short "dwell" and then gradually opens them to reverse the head 12. Preferably a positive stop dog (not shown) is employed under such conditions to assure complete reversal. The time of dwell for a given shift of the pilot valve is always the same and independent of the pressure required to actuate the slide because the fluid effecting the reversal is taken from the conduit 140 and not conduit 61.

The head 12 may also be reversed prior to engagement of the pin 194 with the reversing dog 203 at any time during the "fast feed" or "slow feed" thereof by manually shifting the pilot valve 41 or by actuating the remote control valve 42. With the pilot valve in either "fast feed" position, shown in Fig. 6, or "slow feed" position, shown in Fig. 8, a shift of the remote control valve to the left connects ports 212 and 214. Pressure fluid would then flow from the conduit 140 through conduit 165, conduit 215, ports 214 and 212, and conduit 213 to the bore 156 of the pilot valve. The operating fluid would then shift core 155 of the pilot valve to rapid return position to connect ports 159 and 163 by groove 188 to effect reversal of the head as previously described.

Upon return of the head 12 to starting position, pin 194 strikes stop dog 200 which returns the pilot valve to "stop" position. In that position, as previously described, the chamber behind valve disk 134 is connected to the reservoir through the pilot valve so that the bypass valve maintains only a pressure of approximately 5 pounds in the conduits 60 and 140 which is insufficient to open intake check valve 100. Thus, though the pumps 36 and 37 continue to operate, no fluid is supplied to the motor 35.

While the diagrammatic views (Figs. 4 to 7) show the positive displacement piston pump 37 as having but a single cylinder and piston, it is to be remembered that the pump has in fact a plurality of cylinders and pistons with each cylinder connected in the manner here shown, as more particularly disclosed in my copending applications Serial No. 60,646, filed January 24, 1936, now abandoned, and Serial No. 141,327, filed May 7, 1937.

The term "unmetered," employed throughout the specification and claims in describing the fluid supplied by the rotary pump 36, is not intended to mean that the discharge from pump 36 is irregular and indeterminate. The term is employed merely to characterize and distinguish the slightly variable and, in this instance, large output of a rotary pump from the minutely measured and, in this instance, small output of a positive displacement piston pump. The terms "metered" and "unmetered" are primarily a matter of degree. Furthermore they are employed in the sense that during "feed" of the support the piston pump 37 measures or meters the quantity of fluid supplied while during "rapid traverse" fluid flows through the piston pump in quantities independent of the displacement thereof and thus is unmeasured or unmetered thereby.

It will be apparent from the foregoing that I have provided a unique circuit which among other advantages is extremely simplified over circuits heretofore employed to accomplish the same movements. Feed, rapid traverse, or no movement of the head are obtained simply by variation of the pressure of the fluid source. The circuit also positively locks the head against movement in either direction when the pilot valve is in stop position. Neither the check valve 101 nor the valve 39 yield to pressure built up within the motor by the application of external force to the head.

I claim as my invention:

1. A hydraulic circuit comprising a hydraulic motor for imparting movement to a member at different speeds, a first means for supplying a large quantity of fluid to said motor at a high rate to impart a high speed to the member, a second means for supplying a smaller metered quantity of fluid to said motor at a lower rate to impart a lower speed to the member, and a single control unit governing the rate at which fluid is supplied to said motor to determine the speed of movement of the member, having a first adjustment rendering said first means effective to supply fluid to said motor to drive the member at a high speed, a second adjustment rendering said second means effective to supply fluid to drive the member at a lower speed, and a third adjustment rendering both said first and said second means ineffective to supply fluid to said motor whereby the member is at rest.

2. A hydraulic circuit comprising a hydraulic motor for imparting movement to a member at different speeds, a first pump for supplying a large quantity of fluid to said motor at a high rate to impart a high speed to the member, a second piston pump for supplying a smaller metered quantity of fluid to said motor at a lower rate to impart a lower speed to the member and interposed between said first pump and said motor, a control means adjustable to be variably responsive to fluid pressure determining which of the fluid supplying means is effective to supply fluid to said motor to govern the speed of movement of the member, and means effecting the adjustments of said control means.

3. In a hydraulic circuit a hydraulic motor, a variable pressure pump for supplying operating fluid to said motor, fluid metering and pressure boosting means interposed between said pump and said motor operable under predetermined pressure conditions to meter the quantity of fluid passing therethrough and operable under other pressure conditions to permit free unmetered flow therethrough, and control means governing the pressure of the fluid supplied to said metering and boosting means by said variable pressure pump to obtain a metered or an unmetered supply of fluid to the motor.

4. A hydraulic circuit comprising a hydraulic motor for driving a member at different speeds, a large output pump for supplying operating fluid to said motor at a high rate to drive the member at a high speed, a passage leading from said pump to said motor, a first and a second check valve in the passage disposed to permit flow in a direction from said pump to said motor but preventing flow in the opposite direction, means seating said second check valve to permit opening thereof only upon the creation of a predetermined pressure higher than that required to open the first check valve, a positive displacement pump of smaller capacity than said large output pump communicating with the passage leading from the large output pump to said motor intermediate the check valves and operable to supply a metered quantity of fluid to said motor at a lower rate to drive the member at a lower speed, and control means governing the rate at which fluid is supplied to said motor having a first adjustment in which fluid is supplied to the motor in accordance with the capacity of the large output pump to drive the member at a high speed and a second adjustment in which a metered quantity of fluid determined by the output of the positive displacement pump is supplied to said motor to drive the member at a lower speed.

5. A hydraulic circuit comprising a hydraulic motor for driving a member at different speeds, a variable pressure large output pump for supplying fluid to said motor at a high rate, a positive displacement piston pump for supplying fluid at a lower metered rate having each cylinder of the pump connected between the large output pump and the motor so that all fluid supplied to the motor flows through the piston pump, an intake check valve for each cylinder, an exhaust check valve for each cylinder, both of said check valves being disposed to permit flow only in a direction from said large output pump to the motor, and control means determining which of said pumps is effective to supply fluid to said motor so as to obtain a large unmetered supply of fluid for driving the member at a high speed or a smaller metered supply of fluid for driving the member at a lower speed.

6. A hydraulic circuit comprising a hydraulic motor for driving a member at different speeds, a variable pressure large output pump for supplying fluid to the motor at a high rate to impart a high speed to the member, a positive displacement piston pump for supplying fluid at a lower metered rate having each cylinder of the pump connected between the large output pump and the motor so that all fluid supplied to the motor flows through the piston pump, an intake check valve for each cylinder permitting flow only into the cylinder and opening only at a predetermined pressure, an exhaust check valve for each cylinder permitting flow only out of the cylinder and opening only at a pressure higher than that required to open the intake check valve, and control means determining the rate at which fluid is supplied to said motor having a first adjustment causing the discharge pressure of the large output pump to equal the pressure at which the exhaust check valve opens to obtain an unmetered flow to the motor of a large quantity of fluid through the piston pump to drive the member at a high speed, and a second adjustment causing the discharge pressure of the large output pump to exceed only the pressure at which the intake valve opens to obtain a metered flow of fluid to the motor at a rate determined by the displacement of the piston pump, for driving the member at a lower speed.

7. A hydraulic circuit comprising a hydraulic motor for driving a member at different speeds, a continuously driven variable pressure pump of large output for supplying fluid to said motor at a high rate, a continuously driven positive displacement piston pump for supplying fluid at a lower metered rate having each cylinder of the pump connected between the large output pump and the motor so that all fluid supplied to the motor flows through the piston pump, means for imparting an exhaust stroke only to the piston in each cylinder, an intake check valve for each cylinder permitting flow of fluid only into the cylinder, an exhaust check valve for each cylinder permitting flow of fluid only out of the cylinder, means controlling the exhaust check valve to permit opening thereof only at a pressure substantially higher than that required to open the intake check valve and impart an intake stroke to the piston in the cylinder, and a bypass valve connected between said large output pump and

the intake check valve of each cylinder having a first adjustment preventing any bypassing of fluid therethrough whereby all fluid discharged by the large output pump flows unmetered through the piston pump to the motor to impart a high speed to the member, and a second adjustment maintaining a pressure of the fluid discharged by the large output pump capable of opening the intake check valve and of imparting an intake stroke to the piston, but incapable of opening the exhaust check valve whereby the piston pump supplies a metered quantity of fluid to said motor to drive the member at a lower rate, said bypass valve bypassing the excess of fluid supplied by the large output pump over that metered by the piston pump.

8. A hydraulic circuit comprising a hydraulic motor for driving a member at different speeds, a continuously driven variable pressure pump of large output for supplying fluid to said motor at a high rate, a continuously driven positive displacement piston pump for supplying fluid at a lower metered rate having each cylinder of the pump connected between the large output pump and the motor so that all fluid supplied to the motor flows through the piston pump, means for imparting an exhaust stroke only to the piston in each cylinder, an intake check valve for each cylinder permitting flow of fluid only into the cylinder, an exhaust check valve for each cylinder permitting flow of fluid only out of the cylinder, means controlling the exhaust check valve to permit opening thereof only at a pressure substantially higher than that required to open the intake check valve and impart an intake stroke to the piston in the cylinder, and a double bypass valve connected between the large output pump and each intake check valve for determining the rate at which fluid is supplied to said motor by controlling the discharge pressure of the large output pump having a first adjustment at which no fluid is bypassed thereby maintaining a discharge pressure of the large output pump capable of opening both check valves to obtain an unmetered flow of fluid to said motor at a high rate, a second adjustment maintaining a discharge pressure capable of opening only the intake check valve to obtain a supply of fluid to said motor at a metered rate determined by the displacement of the piston pump, said bypass valve bypassing the excess of fluid supplied by the large output pump over that metered by the piston pump, and a third adjustment maintaining a discharge pressure of the large output pump incapable of opening the intake check valve whereby all fluid is bypassed and no fluid is supplied to said motor.

9. In a hydraulic circuit for reciprocating a member, a hydraulic motor, a reversing valve directing the flow of fluid to and from said motor, a pump through which passes all of the fluid supplied to said hydraulic motor, said pump being operable under predetermined conditions to meter the quantity of fluid supplied to the hydraulic motor and to boost the pressure of the fluid, and operable under other conditions to provide a passage for the unmetered flow of fluid, and means including a source of fluid under pressure controllable to render the pump capable or incapable of metering the quantity of fluid passing therethrough.

10. A hydraulic circuit comprising a reversible hydraulic motor for imparting movement to a member at different speeds and in opposite directions, a first pump for supplying a large quantity of fluid to said motor at a high rate to impart a high speed to the member, a second pump for supplying a smaller metered quantity of fluid to said motor at a lower rate to impart a lower speed to the member, means for driving said pumps continuously, a reversing valve for directing the fluid supplied to said motor to effect reversal thereof, a bypass valve connected in circuit with said pumps in a manner and having different adjustments rendering either or both of said pumps ineffective to supply fluid to said motor to obtain different speeds of the member, and a pilot valve governing and coordinating said bypass valve and said reversing valve to obtain a predetermined cycle of operation of the member.

11. A hydraulic circuit comprising a reversible hydraulic motor for driving a support of a machine tool through a predetermined cycle, a first pump for supplying a large quantity of fluid to said motor at a high rate to impart a high speed to the member, a second pump for supplying a smaller metered quantity of fluid to said motor at a lower rate to impart a lower speed to the member, means for driving said pumps continuously, a reversing valve for directing the fluid supplied to said motor having an advance and a return position, an adjustable bypass valve having a first adjustment rendering said first pump effective to supply fluid to said motor, a second adjustment rendering said second pump effective, and a third adjustment rendering both pumps ineffective to supply fluid, and a pilot valve controlling said bypass valve and said reversing valve having a position causing the support to be advanced at a high speed, a second position causing the support to be advanced at a low speed, a third position causing the support to be returned at a high speed and a stop position.

12. A hydraulic circuit comprising a reversible hydraulic motor for imparting movement to a member at different speeds and in opposite directions, a first variable pressure pump for supplying a large quantity of fluid to said motor at a high rate to impart a high speed to the member, a supply passage leading from the pump to the motor, a first and a second check valve in the passage disposed to permit flow only from the pump to the motor, a second pump for supplying a smaller metered quantity of fluid to said motor at a lower rate to impart a lower speed to the member, said second pump communicating with the passage intermediate the check valves, a reversing valve for directing the fluid supplied to said motor to effect reversal thereof, means operable to control the discharge of fluid from said motor maintaining a predetermined minimum pressure in the supply passage against which said second check valve opens, a bypass valve connected to the passage intermediate the first pump and the first check valve having selectively different adjustments maintaining the discharge pressure of the first pump above or below the pressure against which said second check valve opens, and a pilot valve coordinating the adjustments of the bypass valve and the position of the reversing valve.

13. A hydraulic circuit comprising a reversible hydraulic motor for driving a member at different speeds and in opposite directions, a first means for supplying fluid at a high rate to impart a high speed to the member, a second means for supplying fluid at a lower metered rate to impart a lower speed to the member, a reversing valve directing the fluid supplied to the motor to effect reversal thereof, means controlling the discharge of fluid from the motor, control means

having selectively different adjustments to determine the rate at which fluid is supplied to said motor, a pilot valve for coordinating and controlling the adjustment and position of said control means and reversing valve to obtain a desired cycle of movement of the member, and a remote control valve operable to shift said pilot valve to initiate the cycle of operation.

14. A hydraulic circuit comprising a hydraulic motor for driving a member through a predetermined cycle of movement at different speeds, a first means for supplying a large quantity of fluid to said motor at a high rate to impart a high speed to said member, a second means for supplying a smaller metered quantity of fluid to said motor at a lower rate to impart a comparatively low speed to the member, means for directing the fluid supplied by said first and second means to effect reversal of said motor, means controlling the discharge from said motor to maintain a minimum pressure in the supply side of the motor under varying load of the member, control means governing the rate at which fluid is supplied to said motor to obtain the different speeds of the member, means coordinating said control means and said reversing means to obtain a predetermined cycle of operation of the member, a remote control for actuating said coordinating means to initiate the cycle of operation, and dogs actuating said coordinating means automatically to change the rate and direction of movement of the member.

15. A hydraulic circuit comprising a reversible hydraulic motor for driving a member through a predetermined cycle of movement at different speeds, a rapid traverse pump for supplying a large quantity of fluid to said motor at a high rate to impart a high speed to the member, a feed pump for supplying a smaller metered quantity of fluid to said motor at a lower rate to impart a comparatively lower speed to the member, a reversing valve for directing the fluid supplied by said pumps to effect reversal of said motor, means controlling the discharge of fluid from said motor responsive to the pressure of the fluid supplied to the motor, control means governing the rate at which fluid is supplied to said motor by said pumps to obtain the different speeds of the member, a pilot valve coordinating said control means and said reversing valve to obtain the predetermined cycle of movement of the member, a remote control valve for actuating said pilot valve to initiate the cycle of movement, and dogs actuating said pilot valve automatically to change the speed and the direction of movement of the member at predetermined points in the cycle.

16. A hydraulic circuit comprising a reversible hydraulic motor for driving a member through a predetermined cycle of movement at different speeds, a variable pressure pump for supplying a large quantity of fluid to said motor at a high rate to impart a high speed to the member, a positive displacement pump for supplying a smaller metered quantity of fluid to said motor at a lower rate to impart a comparatively low speed to the member, a reversing valve directing the fluid supplied by said pumps to effect reversal of said motor, means responsive to the pressure of the fluid discharged by said variable pressure pump yielding when the pressure reaches a predetermined value to permit unmetered flow of the fluid discharged by the variable pressure pump to said motor, means controlling the discharge of fluid from said motor to maintain a minimum pressure at which said first mentioned means yields, a by-pass valve controlling the pressure of the fluid supplied by said variable pressure pump to govern the rate at which fluid is supplied to said motor to obtain the different speeds of the member, said by-pass valve having a first adjustment maintaining a pressure capable of actuating said pressure responsive means to cause all the fluid discharged by the variable pressure pump to be supplied to said motor, and a second adjustment maintaining a pressure incapable of actuating the pressure responsive means so that only the fluid metered by said positive displacement pump is supplied to said motor, a pilot valve for coordinating the adjustments of said bypass valve and the positions of said reversing valve to obtain the predetermined cycle of movement, a remote control valve for actuating said pilot valve to initiate the cycle of movement, and dogs for successively actuating said pilot valve to effect a change in the speed or direction of movement of the member or both at predetermined points in the movement thereof.

17. A hydraulic circuit comprising a reversible hydraulic motor for driving a member through a predetermined cycle of movement at different speeds, a variable pressure pump for supplying fluid to said motor at a high rate to impart a high speed to the member, a piston pump for supplying a metered quantity of fluid to said motor at a low rate to impart a lower speed to the member, said pumps being connected in series so that all of the fluid supplied to said motor passes through the piston pump, a reversing valve for directing the fluid supplied by said pumps to effect reversal of said motors, a first check valve in the passage from the variable pressure pump to said motor permitting flow only in a direction from said pump to said motor and opening at a predetermined pressure, a second check valve in the passage from the variable pressure pump to said motor, also permitting flow only in a direction from the pump to the motor and opening only at a pressure higher than said first check valve, a valve governing the discharge of fluid from said motor, said valve being responsive to and actuated by the pressure of the fluid supplied to said motor, double by-pass valve governing the pressure of the fluid supplied by said variable pressure pump to control the rate at which fluid is supplied to said motor, said by-pass valve having a first adjustment at which no fluid is by-passed and all fluid discharged by said varible pressure pump passes without being metered through the piston pump to said motor, a second adjustment maintaining a pressure capable of opening only said first check valve whereby a metered quantity of fluid is supplied to said motor by said piston pump, and a third adjustment maintaining a pressure incapable of opening either of said check valves whereby no fluid is supplied to said motor, a pilot valve for coordinating the adjustments of said by-pass valve and the position of said reversing valve to obtain a predetermined cycle of movement of the member, a remote control valve actuating said pilot valve to initiate the cycle of operation, and a plurality of dogs actuating said pilot valve to change the adjustment of said by-pass valve and the position of said reversing valve to obtain the predetermined cycle of movement of the member.

18. In a hydraulic circuit having a hydraulic motor, a variable pressure, large output pump and a positive displacement pump, a double by-pass valve connected in circuit with the pumps

and controlling the rate at which fluid is supplied to the motor comprising a casing having a bore therein, two annular valve seats in the bore spaced from the walls of the casing, a supply conduit discharging to the bore and a port leading from the bore, two valve disks slidable in the bore and adapted to engage the respective seats to control the flow of fluid through the valve, a first spring urging one of the valves to seated position yieldable at a low pressure, a second spring urging the other of the disks to seated position yieldable at a higher pressure, and means for maintaining said disks positively seated to prevent the bypassing of any fluid.

19. In a hydraulic circuit for driving a member at different speeds, a variable pressure pump for supplying operating fluid, a bypass valve controlling the discharge pressure of the pump comprising a bore in the valve casing, a tubular member in the bore with its ends spaced radially from the walls thereof to form annular valve seats, a supply port communicating with the bore intermediate the ends of the member, a discharge port communicating with the interior of the member, a first valve disk slidable in one end of the bore, a light spring urging the disk to seated position, a second valve disk slidable in the other end of the bore, a heavy spring urging the disk to seated position to permit opening thereof only at a substantially higher pressure, a small aperture in each disk leading from the supply port to the chambers formed behind the disks, ducts leading from the chambers behind the disks, and valve means controlling said ducts to cause either or both of said disks to be positively held seated by fluid in the chambers behind the disks.

20. In a hydraulic circuit, a hydraulic motor, means supplying operating fluid to said motor including means operative under all conditions to prevent return flow through said fluid supply means, means controlling the flow of all exhaust fluid from said motor, and means responsive only to the pressure of the fluid supplied to the motor governing the means controlling the flow of exhaust fluid from the motor to provide a circuit capable of positively locking said motor against movement by an external force of ordinary magnitude.

21. In a hydraulic circuit, a hydraulic motor, means supplying operating fluid to said motor, a connection between said motor and said fluid supplying means including a check valve preventing return flow through said connection, said connection being the only line leading to the motor, a passage through which flows the exhaust fluid from said motor, a valve solely controlling the flow of exhaust fluid spring pressed to closed position, said last named valve being incapable of opening under the pressure of the exhaust fluid, and pressure responsive means operable to open said valve having communication with the connection between said motor and said fluid supplying means.

22. A hydraulic circuit comprising a reversible hydraulic motor for imparting movement to a member at different speeds and in opposite directions, a first means for supplying a large quantity of fluid to said motor at a high rate to impart a high speed to the member, a second means for supplying a smaller metered quantity of fluid to said motor at a lower rate to impart a lower speed to the member, a reversing valve for directing the fluid supplied to said motor to effect reversal thereof, control means determining which of said fluid supplying means is effective to supply fluid to said motor to obtain the different speeds of the member, a pilot valve governing and coordinating said control means and said reversing valve to obtain a predetermined cycle of operation of the member, and a remote control valve operable to shift said pilot valve to a position for initiating movement of the member.

23. A hydraulic circuit comprising a reversible hydraulic motor for driving a member at different speeds and in forward and return directions, means for supplying fluid to said motor at different rates to obtain a high speed of the member or a lower speed of the member, a reversing valve directing the fluid supplied to said motor to effect reversal thereof, control means governing the rate at which fluid is supplied to said motor, a pilot valve governing and coordinating said control means and said reversing valve having stop, high speed forward, lower speed forward and return positions, and a remote control valve governing a supply of operating fluid for the pilot valve operable to shift the pilot valve from stop to high speed forward position and from lower speed forward to return position.

24. In a hydraulic circuit, a hydraulically shiftable reversing valve having an advance and a return position, a pilot valve having a stop, rapid approach, feed and return position, and a remote control valve operable with the pilot valve in stop position to control a supply of fluid shifting the reversing valve to advance position and the pilot valve to rapid approach position, and operable with the pilot valve in feed position to control a supply of fluid shifting the pilot valve to return position and the reversing valve to return position.

25. In a hydraulic circuit, a hydraulically shiftable reversing valve having an advance and a return position, a pilot valve comprising a casing having a bore and a core slidable therein, a first conduit leading from the bore in the pilot valve to one end of the reversing valve, a second conduit leading from the bore to the other end of the reversing valve, a first pressure fluid supply conduit opening to the bore, a return port leading from the bore, said port and conduits being controlled by the core, a second pressure fluid supply conduit opening to the bore, and a valve in said second supply conduit, said pilot valve core having a first position effectively connecting the bore to said first conduit leading from the bore to the reversing valve and closing said return port and said first supply conduit, a second position connecting the bore to said return port and maintaining said first supply conduit closed, a third position closing said return port and maintaining said first supply conduit closed, and a fourth position connecting said first supply conduit to said second conduit leading from the bore to said reversing valve.

26. A hydraulic circuit comprising a reversible hydraulic motor for driving a member in forward and return directions, a constant displacement pump for supplying fluid to the motor at a high rate to impart a high speed to the member, a variable displacement pump for supplying fluid to the motor at a lower rate to impart a lower speed to the member, said variable displacement pump having a cylinder and a piston movable therein to adjust the displacement of the pump, a reversing valve for directing the fluid supplied by said pumps to effect reversal of said motor, control means governing the rate at which

fluid is supplied to said motor by said pumps to obtain the different speeds of the member, and a pilot valve coordinating said control means and said reversing valve to obtain a predetermined cycle of movement of the member, said pilot valve having a first position adjusting or positioning said control means and reversing valve to obtain a fast speed of the member, and a second position retaining said reversing valve and control means in the same position or adjustment while connecting the supply of operating fluid to the cylinder of said variable displacement pump to actuate the piston in a direction causing a reduction in the displacement of the pump to obtain a slow feed of the member.

27. A hydraulic circuit comprising a hydraulic motor for imparting movement to a member at different speeds, a first pump for supplying fluid to said motor to drive said member at a low rate of movement, a second pump operable to supply fluid to said motor to drive said member at a higher rate of movement, means responsive to the discharge pressure of said second pump controlling the period when said second pump is operative to supply fluid to the motor, and means governing the discharge pressure of said second pump.

28. A hydraulic circuit comprising a hydraulic motor for imparting movement to a member at different speeds, a variable pressure pump capable of supplying a large quantity of fluid to said motor at a high rate to impart a high speed to the member, a positive displacement pump for supplying a smaller metered quantity of fluid to said motor at a lower rate to impart a lower speed to the member, a fluid reservoir from which the operating fluid is drawn, and a valve connected in circuit intermediate the reservoir and at least one of the pumps operable to govern the rate at which fluid is supplied to said motor, said valve having a first adjustment at which no fluid flows therethrough rendering said variable pressure pump effective to supply fluid to the motor thereby driving the member at a high speed, and a second adjustment permitting flow therethrough at a predetermined pressure of fluid displaced by said variable pressure pump for rendering only said positive displacement pump effective to supply fluid at a metered rate to drive the member at a lower speed.

29. A hydraulic circuit comprising a hydraulic motor for imparting movement to a member at different speeds, a variable pressure pump capable of supplying a large quantity of fluid to said motor at a high rate to impart a high speed to the member, a positive displacement pump for supplying a smaller metered quantity of fluid to said motor at a lower rate to impart a lower speed to the member, a reversing valve connected in circuit intermediate said pumps and said motor for directing the fluid to drive the motor in opposite directions, said pumps discharging directly to said reversing valve, a by-pass fluid circuit, and a valve connected in said by-pass circuit operable to govern the rate at which fluid is supplied to said motor, said valve having a first adjustment in which the valve is closed preventing the flow of fluid therethrough for rendering said variable pressure pump effective to supply fluid to the motor thereby driving the member at a high speed, and a second adjustment permitting the flow therethrough at a predetermined pressure of fluid displaced by said variable pressure pump for rendering only said positive displacement pump effective to supply fluid at a metered rate to drive the member at a lower speed.

30. A hydraulic circuit comprising a reversible hydraulic motor for driving a member at different speeds and in opposite directions, means for supplying fluid to said motor at a high rate to impart a high speed to the member or at a lower rate to impart a lower speed to the member, a reversing valve directing the fluid supply to the motor to effect reversal thereof, control means having selectively different adjustments to determine the rate at which fluid is supplied to said motor, a pilot valve for coordinating and controlling the adjustment and position of said control means and reversing valve to obtain a desired cycle of movement of the member, and a remote control valve operable to shift said pilot valve to initiate the cycle of operation.

31. A hydraulic circuit comprising a hydraulic motor for driving a member through a predetermined cycle of movement at different speeds, a first means for supplying a large quantity of fluid to said motor at a high rate to impart a high speed to said member, a second means for supplying a smaller metered quantity of fluid to said motor at a lower rate to impart a comparatively low speed to the member, means for directing the fluid supplied by said first and second means to effect reversal of said motor, control means governing the rate at which fluid is supplied to said motor to obtain the different speeds of the member, means coordinating said control means and said reversing means to obtain a predetermined cycle of operation of the member, a remote control for actuating said coordinating means to initiate the cycle of operation, and dogs actuating said coordinating means automatically to change the rate and direction of movement of the member.

32. A hydraulic circuit comprising a hydraulic motor for imparting movement to a member at different speeds, a first pump for supplying fluid to said motor at a low rate, a second pump operable to supply fluid to said motor at a higher rate, a common conduit through which fluid from said pumps is discharged to said motor, means responsive to the discharge pressure of said second pump controlling the period when said second pump is operative to supply fluid to the motor, means governing the discharge pressure of said second pump, a conduit through which all the fluid is discharged from said motor, and a valve operable to control the flow through said discharge conduit responsive only to the pressure of the fluid supplied to said motor.

33. In a hydraulic circuit, a hydraulic motor, a variable pressure pump for supplying operating fluid to said motor, a fluid supply conduit leading from said pump to said motor, fluid metering and pressure boosting means interposed in said conduit between said pump and said motor operable under predetermined pressure conditions to meter the quantity of fluid passing therethrough and operable under other pressure conditions to permit free unmetered flow therethrough, control means governing the pressure of the fluid supplied to said metering and boosting means by said variable pressure pump to obtain a metered or an unmetered supply of fluid to the motor, a conduit through which the fluid from said motor is discharged, and means in said discharge conduit operable to control the flow of fluid therethrough, said means being responsive to and

solely actuated by the pressure of the fluid supplied to said motor.

34. A machine tool comprising, in combination, a bed, a tool support and a work support relatively movably supported upon said bed, a hydraulic motor for driving one of said supports at feed and traverse rates, pump means operable to supply fluid to said motor at different rates to obtain feed or traverse movement, a single fluid supply conduit connecting said pump means with said motor, a single discharge conduit through which fluid is discharged from the motor both when driven at feed rate and when driven at rapid traverse rate, a valve disposed in said discharge conduit operable to control the flow of fluid therethrough, said valve being non-responsive to the pressure of the fluid discharged, a spring normally urging said valve to closed position, and means responsive to the pressure of the fluid in the supply conduit for urging said valve to open position, said means and said spring being adjusted to cause the valve to assume a wide open position permitting unrestricted discharge when the pressure in the supply conduit equals that required to drive the motor at a rapid traverse rate under no load.

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