

May 11, 1937.

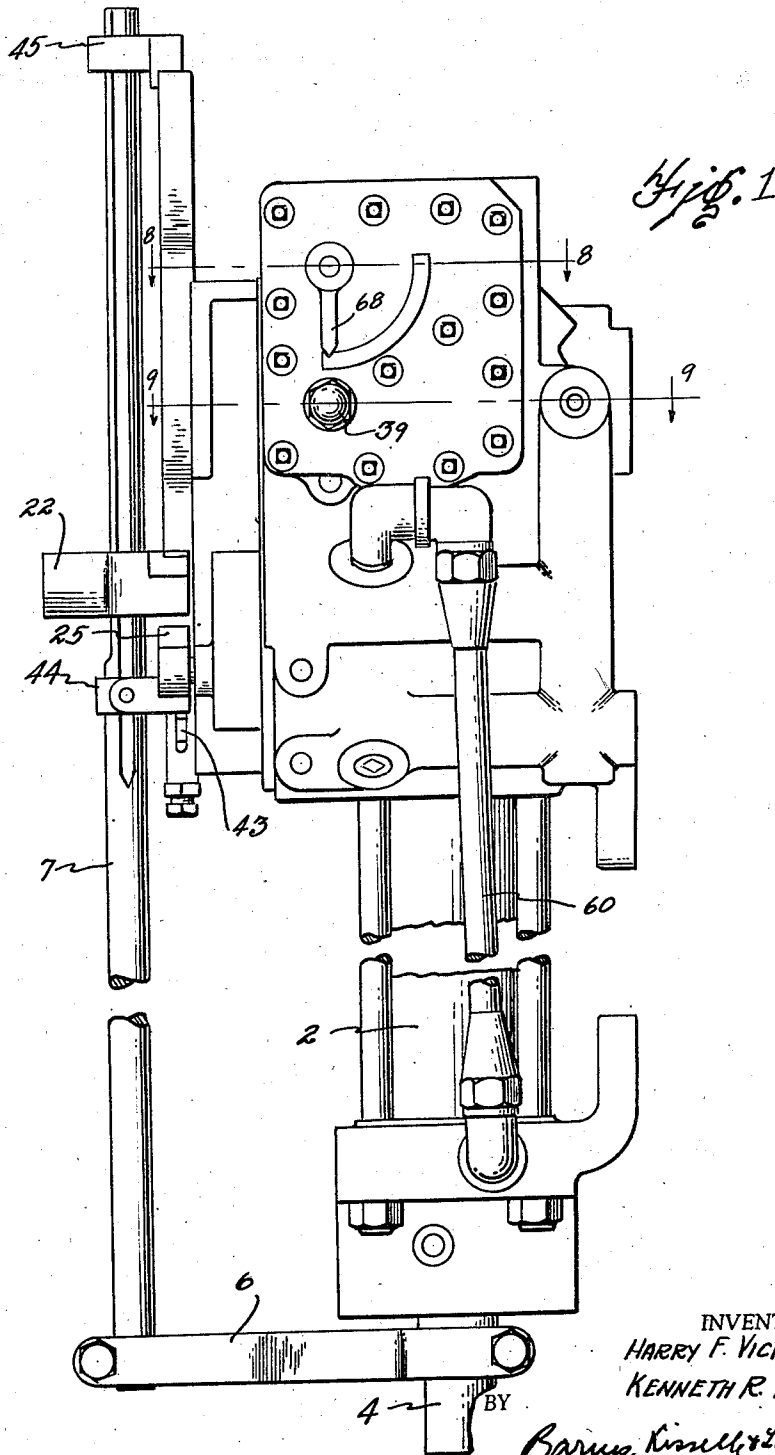
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2,079,640

HYDRAULIC STEP DRILLING UNIT

Filed Jan. 27, 1933

10 Sheets-Sheet 1



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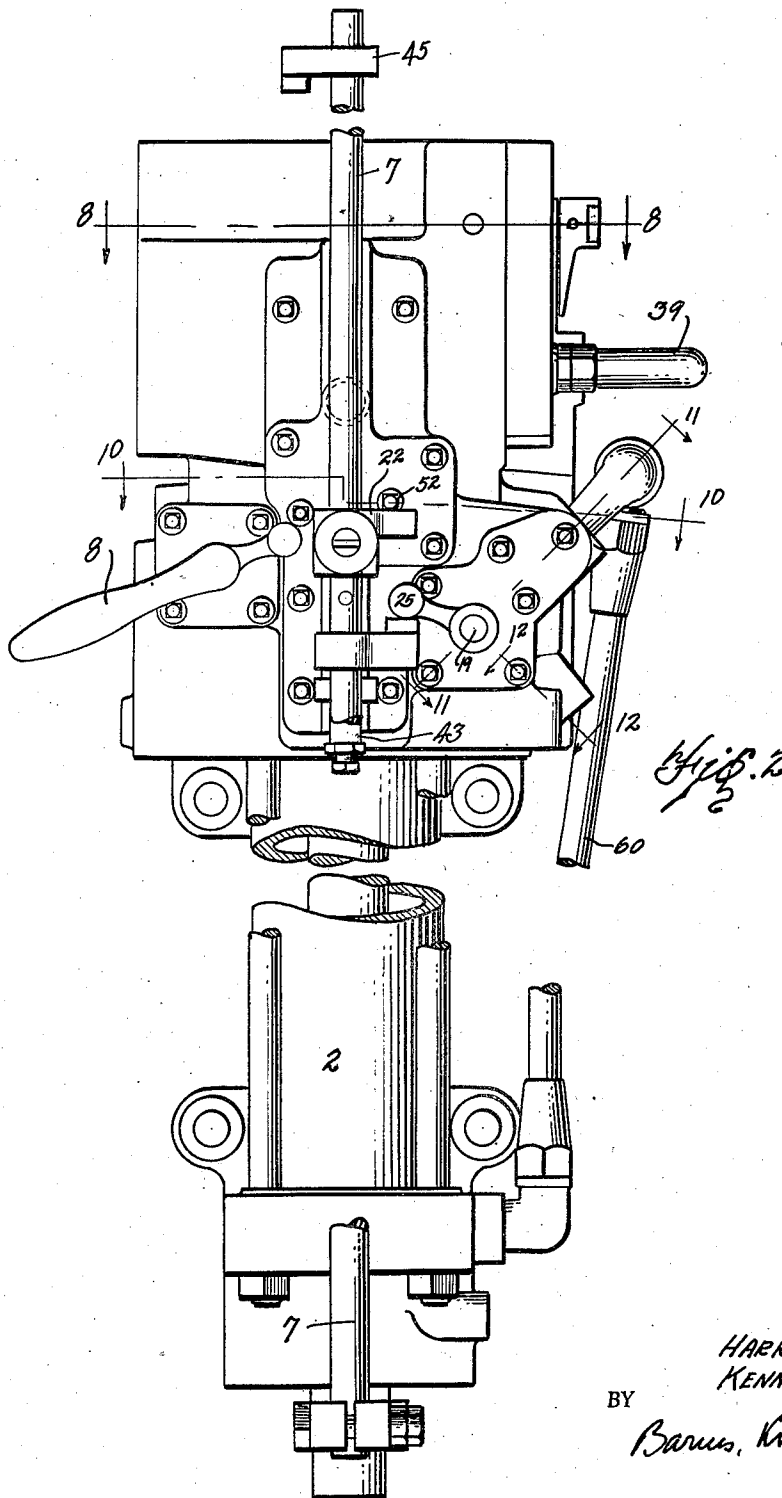
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10 Sheets-Sheet 2



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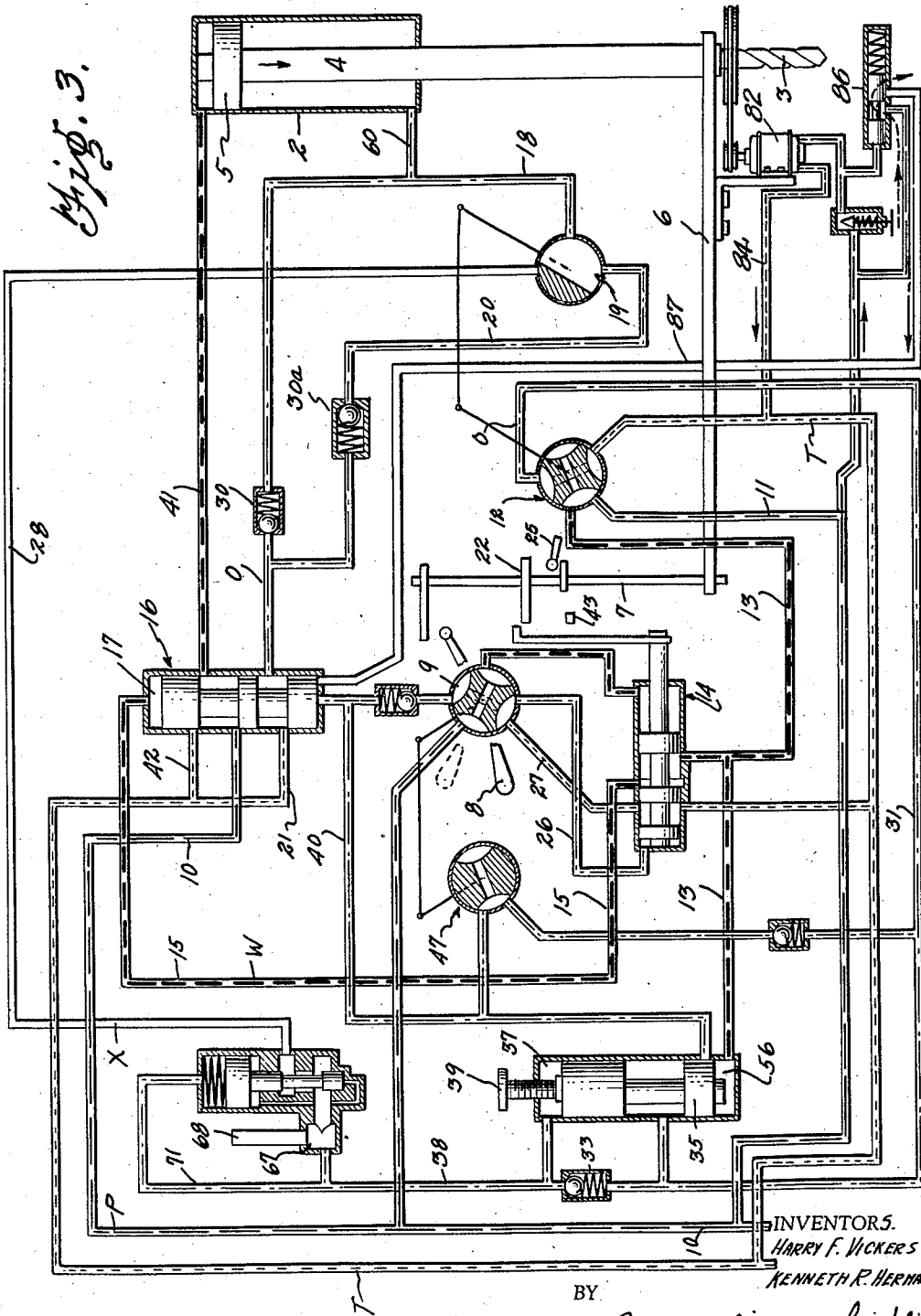
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10 Sheets-Sheet 3



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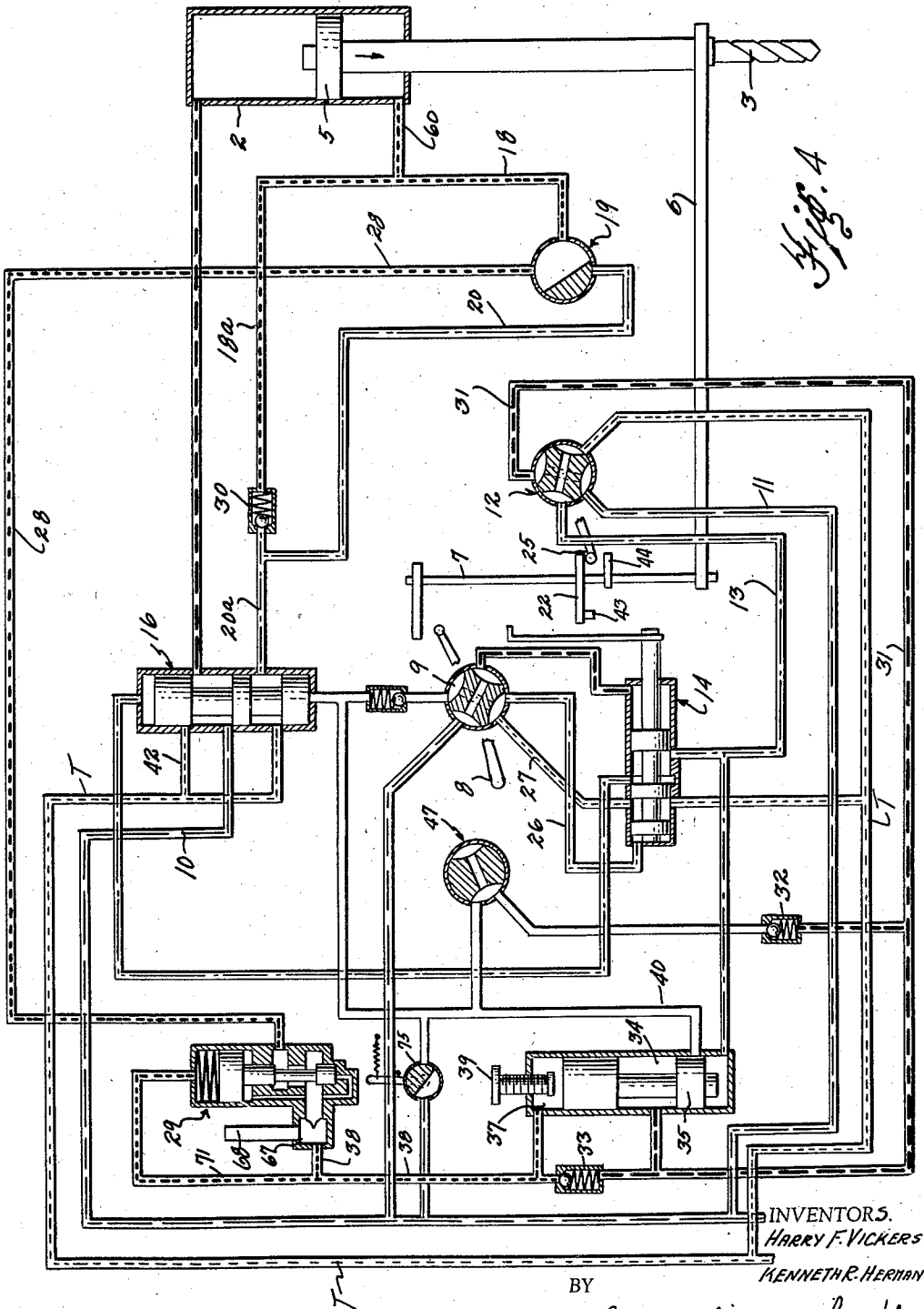
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10 Sheets-Sheet 4



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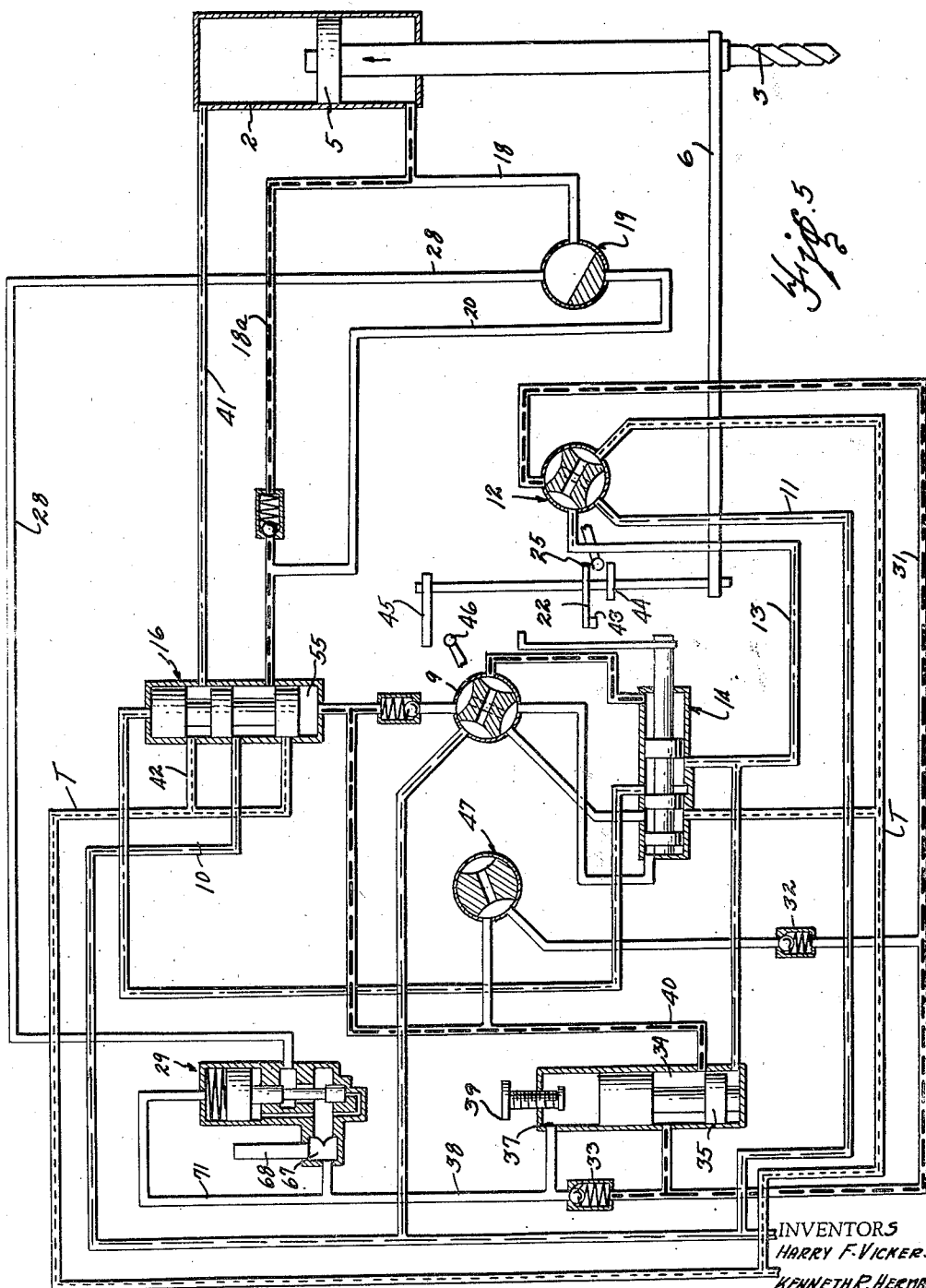
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HYDRAULIC STEP DRILLING UNIT

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10 Sheets-Sheet 5



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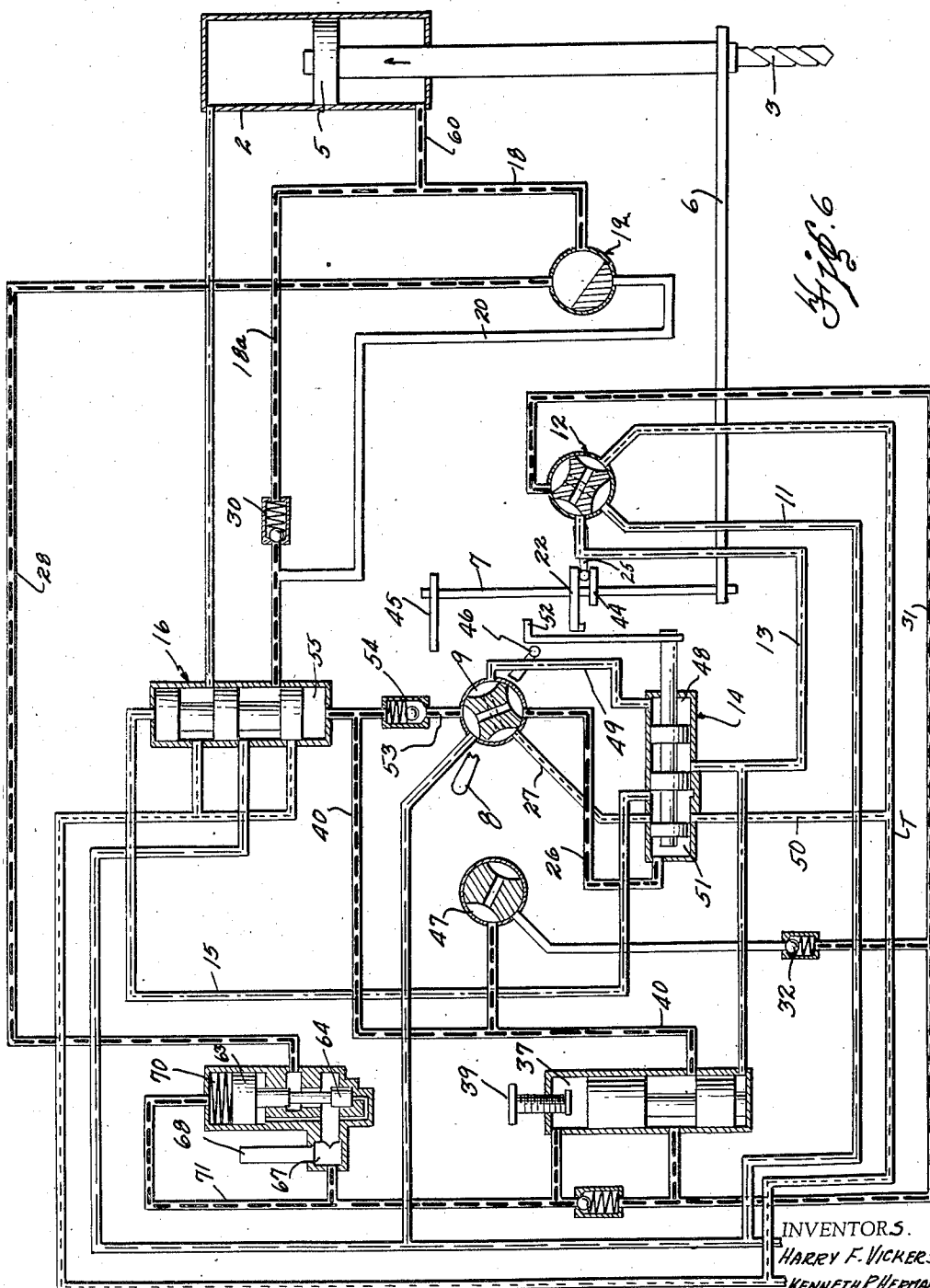
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2,079,640

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Filed Jan. 27, 1933

10 Sheets-Sheet 6



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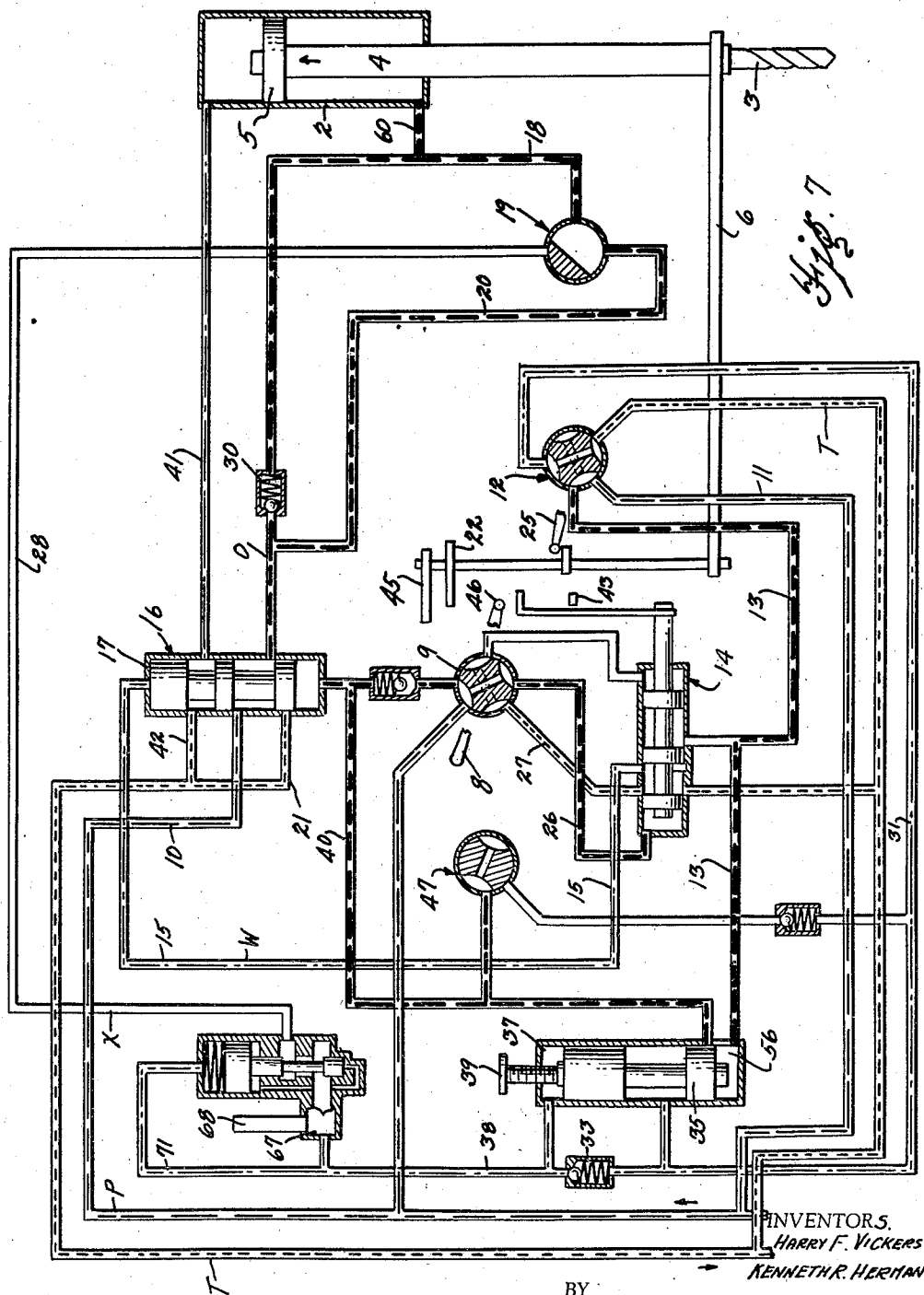
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HYDRAULIC STEP DRILLING UNIT

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10 Sheets-Sheet 7



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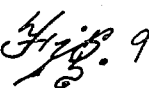
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HYDRAULIC STEP DRILLING UNIT

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10 Sheets-Sheet 8



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HYDRAULIC STEP DRILLING UNIT

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Filed Jan. 27, 1933

10 Sheets-Sheet 9

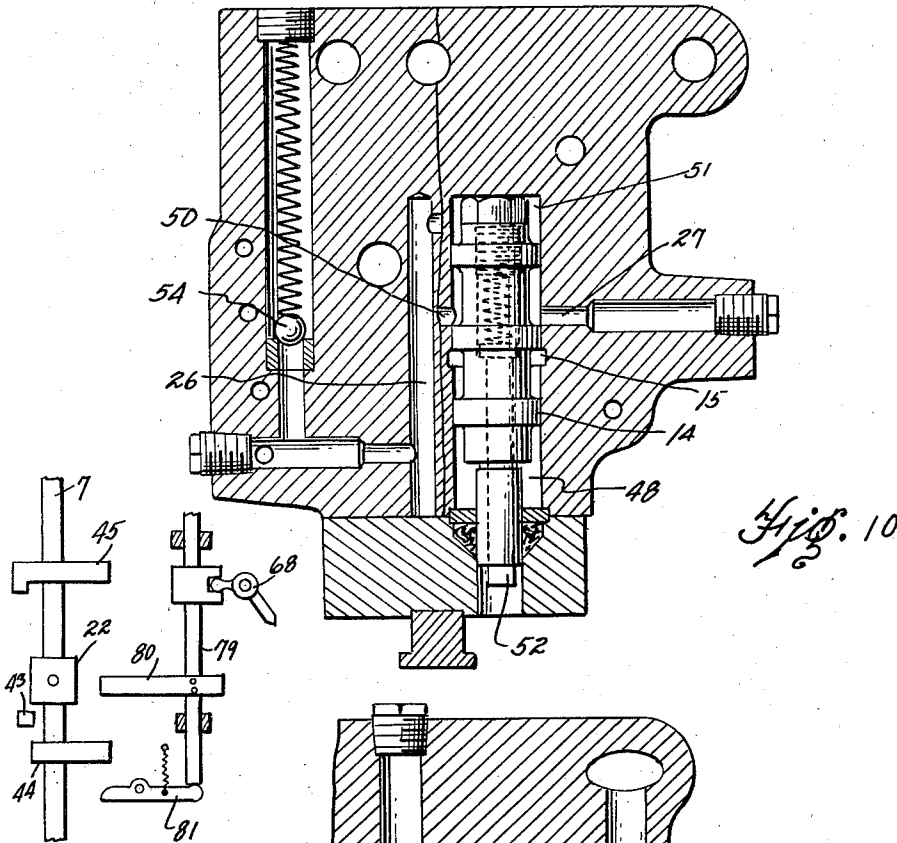


Fig. 10

Fig. 15

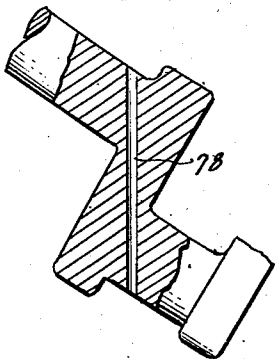


Fig. 16

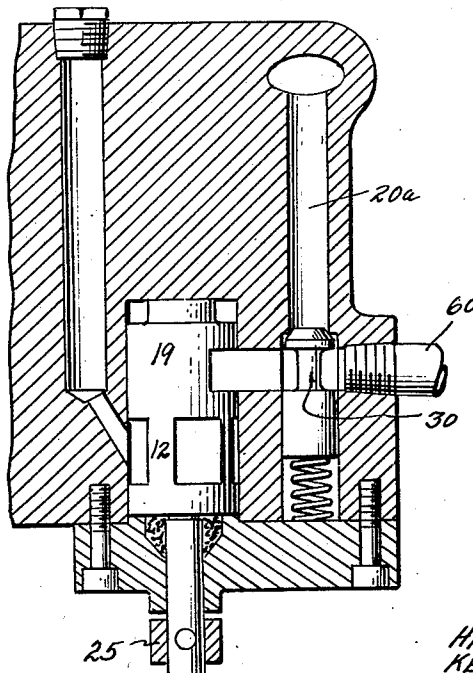


Fig. 11

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10 Sheets-Sheet 10

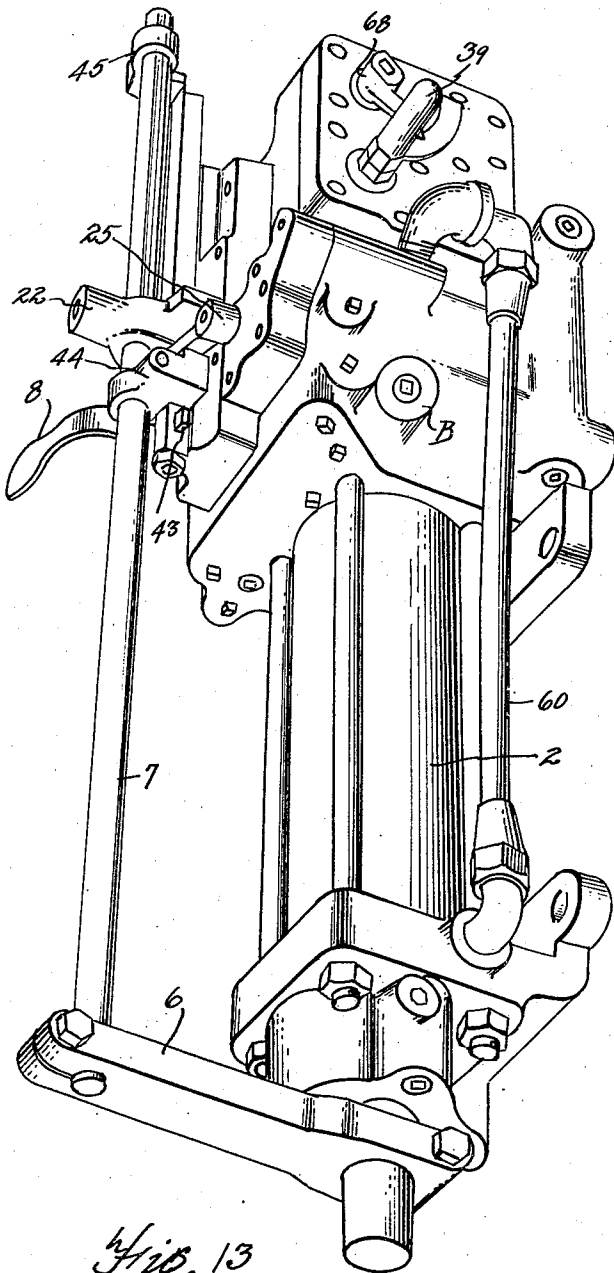


Fig. 13

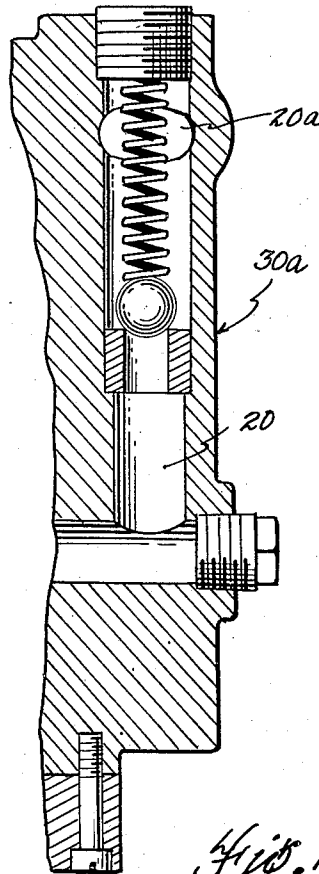


Fig. 12

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UNITED STATES PATENT OFFICE

2,079,640

HYDRAULIC STEP DRILLING UNIT

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Application January 27, 1933, Serial No. 653,822

27 Claims. (Cl. 77—32)

This invention relates to a hydraulic step drilling unit, and has to do particularly with controlled hydraulic drilling by predetermined steps.

Heretofore, numerous attempts have been made to automatically drill holes in metal which have a relatively great depth as compared with their diameter. Most of these attempts at deep drilling have embodied cams having certain portions for controlling the rapid traverse of the drill. Some of these attempts have also included the combination of feed control by mechanical cam and hydraulic or pneumatic means for rapid traverse. However, in using cams, it is not possible to drill very deep or secure a great many steps mechanically, due especially to limitations of cam diameters, and angles, in addition to the mechanical nature of the feed. Other attempts have been made to withdraw the drill when the same exceeds a predetermined amount of thrust, but on small drills such attempts have been unsuccessful due to the fact that when the flutes of the drill become filled with chips the drill often breaks from friction of the chips in the flutes even if the feed is stopped, and on large drills the machine will keep on pulling out if the feed is not accurately and minutely adjusted.

One of the main features of the present invention is the provision of a simple and compact unit for drilling holes in predetermined steps by controlled hydraulic step drilling means; this feature also includes an adjustable control to permit hydraulic step drilling to any depth and in increments of any desired amount at any desired feed rate.

Another important feature has to do with means for controlling the progressive starting and stopping of the feed period. Still another feature relates to the provision of means for changing the rapid traverse movement into a positive feed movement at a predetermined point relative to the termination point of the last feeding step of the drill on the preceding stroke; the direct result being to prevent the drill or tool point from striking the work at high speed and causing drill breakage. This means may or may not be adjustable, but in the preferred form it is made adjustable to prevent any backlash in the linkage from allowing the drills to strike the work at high speed. Another feature resides in the provision of means in combination with a plurality of hydraulic controls for resetting all controls automatically at the completion of the desired drilling depth. Other features embodying details of construction in the

arrangement and combination, including means for obtaining varying lengths of steps, means for withdrawing the drills automatically relative to a predetermined amount of torque, manual means for withdrawing the drill at any time without resetting stops, and means for automatically reducing the feed rate at the start and finish of the drilling operation will be more clearly set forth in the specification and claims.

In the drawings:

Fig. 1 is a side elevation of our hydraulic step building unit as particularly designed to be used as an attachment for a drilling unit.

Fig. 2 is a front view of the structure shown in Fig. 1.

Figs. 3, 4, 5, 6 and 7 are diagrammatic flow sheets showing the respective positions and pressure existing between and in the various connected elements of the complete unit; Fig. 3 illustrating the parts in rapid traverse down position; Fig. 4 representing the parts in feed position; Fig. 5 illustrating the manner of reversing hydraulically at the end of the feed; Fig. 6 illustrating the step of reversing manually when in feed; and Fig. 7 illustrating the step of reversing manually when in rapid traverse down.

Fig. 8 is a sectional view taken on line 8—8 of Fig. 1 and illustrating in particular the means for controlling the rate of feed.

Fig. 9 is a sectional view taken on line 9—9 of Fig. 1 and illustrating particularly the means for controlling the length of feed.

Fig. 10 is a sectional view taken on line 10—10 of Fig. 2.

Fig. 11 is a sectional view taken on line 11—11 of Fig. 2.

Fig. 12 is a sectional view taken on line 12—12 of Fig. 2.

Fig. 13 is a perspective view of the unit and illustrating the preferred general arrangement of the parts going to make up the entire combination.

Fig. 14 is a diagrammatic view illustrating the use of a valve controlled by movement of the drill for draining or by-passing the feed control liquid.

Fig. 15 is a diagrammatic view of means connected to the speed control unit and actuated by the drill movement for decreasing the feed rate when entering and leaving the work.

Fig. 16 is a fragmentary detail view of a crankshaft having an angular hole adapted to be drilled in the manner set forth in Fig. 15.

The general purpose of our hydraulic step

drilling unit is not so much to eliminate manual step drilling but to provide hydraulic means for step drilling which will far surpass results obtained by manual operation by the most skilled machinist. For instance, in a large automobile plant, hydraulic step drilling units constructed in accordance with the present invention are used to drill holes $\frac{1}{8}$ " in diameter and $5\frac{1}{2}$ " deep, the drilling time being two minutes floor to floor and the material .35 carbon alloy steel. In this plant one man operates three machines, and the drills are resharpened every thirty-five holes, while the previous rate was eight to ten holes per resharpening. Drill breakage has been almost entirely eliminated.

A better understanding of the entire unit will be had by here describing the operation, which, in general, is to automatically approach the work with a drill or drills at a rapid traverse rate, next reduce the speed to a feed rate just before contacting with the work, controlling the feed rate for a predetermined distance and then withdrawing the drill or drills at a rapid traverse rate to the starting position. The drill is immediately returned at a rapid traverse rate to a new position which allows a safe clearance above the point, at which the previous feed rate terminated, when the feed rate is again continued for the same predetermined distance as that used in the first drilling step. This cycle is continued automatically until a predetermined total depth is reached, at which point the drill or drills are withdrawn, again at the rapid traverse rate, and stopped at the original starting position.

In the general combination we preferably make use of a constant pressure maintained on the upper side of the piston in the machine operating cylinder, and the metering of the liquid returning from the lower side of this piston to control the feed rate, rapid traverse being obtained by simply bypassing the feed rate control valve. Furthermore, in the preferred combination the measurement of the individual feed rate steps is accomplished by measuring the amount of liquid allowed to escape from the lower side of the operating piston through a feed rate controlled valve, the filling of the measuring chamber causing the actuation of a four way reversing valve, which in turn controls withdrawal of the tools at the end of each drilling step.

In the diagrammatic flow sheets illustrated in Figs. 3 to 7 the power cylinder is shown as at 2 and a drill 3 connected directly to the lower end of a piston rod 4, although it will be understood that the drill mechanism may be connected to the hydraulically actuated member 4 in many different ways. Complete reciprocating control of the drill 3 is obtained through the hydraulic operation of the piston 5. A cross head 6 connects the operating rod 4 to a movable stop control rod 7, said stop control rod moving in unison with piston 5. In illustrating the operation of the various conduits and the position of parts as shown in Fig. 3, the tank return lines are indicated as at T, the inoperative conduits are indicated by plain lines marked X, the conduits operating under continuous pressure are indicated as at P with long thin dashes, the working pressure lines are indicated by the heavy dashes as at W, and the conduits which are open to the tank or tank return lines are indicated by the dot and dash lines as at O.

In the circuit shown in Fig. 3, the handle 8 of the main valve 9 has been moved from the in-

operative dotted line position to the solid line position with the result that the circuit has been put in operation such as will give a rapid traverse down movement of the drill. In this position of the valve, pressure from the main line 10 flows through the conduit 11 and the valve 12 to the conduit 13 through the valve 14 and the conduit 15, and thus entering the top of the shifting valve 16. The application of pressure in the chamber 17 will shift the piston of the valve 16 to the position shown, thus allowing oil under pressure from the main line 10 to flow into the cylinder 2 above the piston 5 and causing such piston to be driven downwardly. The oil in the lower side of the cylinder 2 escapes through the conduit 18, valve 19, conduit 20, valve 16 and conduit 21, to the tank or reservoir. It will be understood here that the valves 12 and 19 are connected to the same valve operating shaft as shown at 12-19 in Fig. 11.

Movement of the cross head 6 continues in a downward direction and as rapidly as oil is available until the stop 22 engages lever 23 of the valve 12. Inasmuch as the valve 12 is connected to valve 19 these two valves will now rotate in unison. The rotation of the valve 19 places this circuit in operating condition as per the flow sheet shown in Fig. 4. Referring to Fig. 4 the valve 9 remains in the position shown for directing oil under pressure to the right hand end of the valve 14 and directing the oil from the left hand end of the valve 14 through the conduit 26 valve 9 and conduit 27 to the tank return line T.

In the flow sheet shown in Fig. 4 pressure still remains on the upper side of the piston 5. Escapement of oil from the lower side of the piston 5 can no longer pass through valve 19 and conduit 20, but is diverted through conduit 28 to the feed control, or speed control, assembly unit 29. The structure and operation of this speed control unit 29 is fully described and claimed in application No. 543,908. Oil is prevented from escaping through the line 18a by the check valve 30. The valve 12 no longer supplies pressure through the line 13 as movement of this valve has diverted the pressure from conduit 11 to conduit 31, which conduit applies pressure against the check valves 32 and 33, and also creates pressure in chamber 34 which surrounds the metering cylinder piston 35. Oil escaping from the lower side of the piston 2 through the feed control valve 29 enters the chamber 37 by way of the conduit 38 thus moving the piston 35 as the chamber 37 fills. A very important point of the present invention is the fact that the capacity of the chamber 37 may be varied by an adjusting screw 39, as adjustment of this screw obviously will limit the stroke of the piston 35. The piston 5 continues to travel downwardly at a feed rate until the port of the metering cylinder or, in other words, until the chamber 34 is opened to the conduit 40, or still in other words, until the pressure in the chamber 34 is connected to the inoperative conduit 40.

Oil will then flow through the conduit 40 to the chamber in the bottom of the cylinder 16 which will shift the valve to its uppermost position or that position shown in Fig. 5. This shifting of the valve in cylinder 16 will remove pressure from the upper side of the piston 5 and will in turn apply pressure from the line 10 to the conduit 20a and conduit 18a, lifting the check valve 30. Return oil from the cylinder 2 passes through the conduit 41, cylinder 16 and out the 75

conduit 42 to the tank return line T, thus allowing rapid traverse upwardly.

During the time that the feed rate is in progress, as shown in Fig. 4, stop 22, which is slidably attached to the stop rod 7, by requiring considerable friction to move it on the rod, has come in contact with the permanently located stop 43, after having shifted valves 12 and 19 through contact of the stop 22 with the lever arm 25 of the valves 12 and 19. Continued advancement of the piston 4 and hence the rod 7 will slide the stop 22 upon the rod 7 thus increasing the distance between the permanently located stop 44 and the slidable stop 22. When return rapid traverse occurs, due to the conditions previously described, such rapid traverse continues upwardly until the stop 44 contacts lever 25, and shifts the valves 12 and 19 to the position shown in Fig. 3. This cycle repeats itself during one drilling operation exactly as described in Fig. 3 except that the distance between the stops 22 and 44, now being greater, a longer rapid traverse approach will occur which is equivalent to the distance drilled during the first step. This cycle will continue, each traverse being longer by the amount drilled during the preceding step, until the predetermined total depth is reached. The rapid traverse up and the lines under flow are shown in Fig. 5 and described in the next above paragraph.

Referring now to Fig. 6, the various positions of parts and conditions of pressure are shown which occur when the final depth of the hole has been reached, and the final rapid traverse return is in progress. At this point of the cycle, on the last down stroke, a stop 45 permanently connected to the upper end of the rod 7 contacts with the projecting end 46 of the lever 8, shifting the valves 9 and 47 which are connected to the same operating shaft and hence move together. Coincident with this operation, pressure is removed from the chamber 48 of the valve 14, through conduit 49, valve 9 and conduits 27 and 50. The shifting of the valve 9 will also apply pressure to the chamber 51 through line 26, thus moving the piston in valve 14 to the right and causing the projection 52 to intercept the upward path of movement of the stop 22 and thus causing the rod 7 to be frictionally pushed through the stop 22 during the rapid stroke upward, such rapid stroke upward having been caused by the valve 9 supplying pressure through the conduit 53, check valve 54 and into the line 40, and also the chamber 55 of the valve 16, the upper chamber in the valve 16 being connected to the tank return by means of the conduit 15 and conduit 59. Thus the conduit 13 is disconnected from the conduit 15 due to the movement of the valve 14 from the position shown in Fig. 3 to the position shown in Fig. 6. The closing of the valve 47 will prevent the escape of pressure from the conduit 40 and through check valve 32.

As shown in Fig. 7, the closing of the valve 47, and conduit 13 by the valve 14, renders the valve 12 inoperative so that the shifting of the lever 25 at the upper end of the return stroke has no effect upon valve 16 with the result that the piston 5 remains at rest at the upper end of the last return stroke, pressure being maintained against the lower side of the piston until such time as lever 8 is again moved to place the valves and communicating conduits in the position shown in Fig. 3.

It will be obvious from a study of Figs. 3 to 7 that it is possible for the operator to reverse the

machine at any time by operating the lever 8 manually, the result being the same whether the valves 9 and 47 are shifted manually or mechanically. Fig. 6 illustrates the condition of the circuit and valves if the lever 8 is shifted manually when the drill press is in feed. Fig. 7 also illustrates the various circuits and valve positions if the drill is reversed when in rapid traverse down.

As previously described, reversal occurs automatically due to the filling of the chamber 37, allowing the pressure in chamber 34 to escape through the conduit 40 and shift the four way valve 16. Referring to Fig. 3 it will be noted that during rapid traverse down the valve 12 will have supplied liquid under pressure to chamber 56, pushing the piston 35 against the adjusting tool 39 and exhausting chamber 37 through the check valve 33, conduit 31, and through the valve 12 to the tank return conduit T, thus placing the metering chamber 37 in operable position for the feed cycle which immediately follows. It will be understood that reversing of the piston 35 at the beginning of a stroke can be accomplished at a different period, such as during the rapid traverse up, but we prefer to reverse the piston 35 during the rapid traverse down or, in other words, just before the feed period.

The important feature of the circuit is the fact that the clearance between the finish of the rapid stroke downward (or the start of the feed period) and the contact of the drill with the bottom of the hole, can be regulated by making the position of the stop 43 adjustable so that the sliding stop 22 may have varying positions between the point where the valve 19 is cut off and the point where the stationary stop 43 contacts the sliding stop 22. Thus the stop 43 will, of course, be adjusted at the beginning of the drilling operation to suit the particular work being drilled, and may also be adjusted any time during the drilling operation if the operator thinks that the clearance is too small or too great.

In Fig. 8 we have shown a detail of the feed control assembly 29. This feed control assembly is more fully described in copending application No. 543,908, filed June 12, 1931. In the operation of this unit for controlling the speed of the liquid actuated element, in this case the feed of the drill, the liquid under pressure from the exhaust side of the cylinder 5 enters through the conduit 28 and into the valve chamber 61. The spring 62 normally acts upon a piston 63 to hold valve 64 whereby liquid entering through the conduit 28 will fill the chambers 61 and 69, enter the passageway 65 and fill the chamber 66 thus creating pressure under the piston 63 tending to move it towards valve closing position. If this pressure should be sufficiently high it will completely overcome the spring 62 to effect closing of the valve 64. Upon moving of the orifice valve 67 by the handle 68 to a predetermined point, the liquid will flow past the orifice of this valve to the conduit 38 and then to the displacement chamber 37, and then later through the valve 12 to the return tank, as previously described. When the valve 67 is opened, a pressure drop occurs which will result in the spring 62 opening the valve 64 and admitting additional liquid in the chamber 69 whereby to instantly build up pressure in chambers 69 and 66 to move the piston 63 towards valve closing position. Inasmuch as the orifice control valve 67 will have been set at a certain feed rate, the outlet of liquid from the chamber 69 will be continuous and therefore the inlet of liquid past the valve 64 will

also have to be continuous to maintain a pressure in the chamber 69. The piston 63 will be automatically positioned so that just sufficient liquid is admitted past the valve 64 to the chambers 69 and 66 to maintain pressure sufficient to partially overcome the spring 62. Pressure in the chamber 69 will be maintained constant, for any given spring, regardless of the opening of the orifice provided in the valve 67. Any tendency to increase the pressure in the conduit and in the chamber 61 will be immediately reflected in the chamber 66 to raise the piston and valve 64 towards closing position. Likewise any pressure drop in the chamber 69 will be immediately reflected in the chamber 66, the spring 62 will immediately open or enlarge the opening past the valve 64 and admit more liquid to the chamber 69 to maintain pressure therein. Thus uniform pressure is maintained in the chambers 69 and 66 regardless of the pressure in the chamber 61 and since uniform pressure is maintained in the chamber 69, the flow past the orifice valve 67 must always be at the same rate for any given position, it being understood of course, that any change in oil viscosity due to a change in temperature will be negligible.

The valve 64 preferably has a threaded fit with the piston 63 to permit replacement of different valves and valve stems. Normally the diameter of the valve 64 is of the same diameter as the enlarged portion of the valve stem within the chamber 61 or adjacent the piston 63 so that the pressure in the chamber 61 will not impart either a downward or upward force on the piston 63. With this construction, and with the valve 67 set in a certain place, a constant speed or feed rate is maintained irrespective of any change in load. However, in many instances it may be desirable to change the feed rate, for instance, if desired to increase the rate of feed as the load increases, the effective diameter of the valve stem adjacent the piston 63 may be made larger than the effective diameter of the valve 64 whereby any drop in pressure in the line 28 due to a sudden increase in load will cause an increase in pressure in the chamber 69, thus maintaining increased speed during the effective period of said increase in load. In other words, by proportioning the relative areas of the valve 64 and valve stem adjacent the piston 63, any decrease in pressure due to load can be made to increase or decrease pressure in the chamber 69 thus increasing or decreasing the feed rate. The space 70 on the other side of the piston 63 is in communication, by means of a conduit 71, with the outlet 38 in the valve 29 to compensate for any back pressure under any operating conditions as, for instance, the resistance created by a relatively long pipe connected to the outlet 38. Adjustment of stop 45, of the valve stem 68 and the stop 39 provides step drilling of any desired depth in increments of any desired amount and at any desired feed rate, all accomplished hydraulically and through the same control means namely, the cylinder 2 and piston 5.

Fig. 9, which is a sectional view taken on line 9—9 of Fig. 1, illustrates the compact, practical design of our control valve 16 and hydraulic displacement unit including the piston 35 and the adjusting screw 39. A pump 73 is diagrammatically shown as being connected into the conduit 10. This pump is preferably of the continuously operating constant displacement type. While the various conduits and control elements connecting and embodied in the control valve 16

and displacement unit are diagrammatically illustrated in Figs. 3 and 4, Fig. 9 illustrates the arrangement and location of these various connecting conduits and connections in one simple, compact unit.

Fig. 10 is a sectional view taken on line 10—10 of Fig. 2. This cross sectional view illustrates the practical design of the control piston and cylinder 14, the piston being shown in its innermost position corresponding to Figs. 3, 4 and 5, the spring backed plunger stop 52 also, of course, being in retracted position, and the center piston member being positioned between the ports communicating with the conduits 15 and 27. If the valve 14 should be shifted when there is any interference with stop 52, the spring will be depressed and thus prevent breakage of any of the parts. Normal contact is at right angles to the stop 52.

Fig. 11 is an enlarged sectional detail view taken on line 11—11 of Fig. 2 and illustrating particularly the manner of mounting valves 12 and 19 on the same shaft so as to be controlled by the lever 25. The compactness of this structure as compared to the diagrammatic arrangement in Fig. 3 is well illustrated when reference is made to the valves 12 and 19, conduit 60 and check valve 30.

Fig. 12 is a sectional view taken on line 12—12 of Fig. 2 and illustrates the detailed structure of the check valve unit 30a shown in its correct position of operation in Fig. 3. It is obvious that this check valve is operative when used to cooperate with the valve 19 and set up back pressure against the piston 5 in its downward movement.

Means for withdrawing drill at any time without resetting stops is shown diagrammatically in Fig. 4 and consists of a manually operated pilot valve 75 which serves as a by-pass direct from the pressure line to line 40 for the purpose of shifting the 4-way valve, and causing return of the unit at any time without resetting the stops. The operation of this is as follows: Suppose we are drilling with a $\frac{1}{8}$ " drill and progressing by $\frac{1}{8}$ " steps, normally these steps are short enough so no clogging of chips in the drill will occur. Nevertheless, this clogging will happen occasionally. The operator is made aware of the chips clogging by noise or chatter of the drill, and he simply moves the emergency return lever of valve 75 admitting oil under pressure into line 40, which causes the drill to pull out, thus clearing itself but not in any other way disturbing its cycle. Immediately after the rapid pull out of the drill, it will return to work at the point where it was disturbed, and continue to drill the hole in $\frac{1}{8}$ " steps. If control lever 8 were used for this purpose all stops would be reset, and the time which it would take to feed back to the point of interruption would be lost.

Fig. 14 illustrates more or less diagrammatically a method for securing varying lengths of steps. For example, when drilling with a $\frac{1}{8}$ " drill it may be desirable and possible to drill one inch in depth before it is necessary to start drilling in steps. It is also possible that after drilling one inch, the next step might be one-half inch, and then the last ones $\frac{1}{8}$ ". The method of accomplishing this result is to provide a small valve 76 operated by recesses and projections 77 on rod 7 and connecting line 38 or the chamber 37 to the tank return. The valve 76 is opened by contacting with a depression 77 which, when open, provides a leak from chamber 37, and pre-

vents this chamber filling due to oil being normally supplied to it through line 38. Feed will then be continuous until one of the projections on rod 7 closes the valve, which will cause chamber 37 to fill, thus pulling out to clear the drill. Any number or combination of drilling steps may be provided by this method.

Fig. 15 diagrammatically illustrates a method for decreasing the feed rate when entering or finishing the drilling of a hole 78 in a crankshaft as shown in Fig. 16. This change in feed rate is accomplished by controlling the movement of the speed control lever 68 with a rod 79 provided with a rigidly attached contact member 80 and a pivoted return cam 81, and by having stop 45, which limits the final reversal point of the drill, contact projection 80 attached to rod 79, sliding it downwardly and rotating feed valve lever 68 so as to decrease the feed rate while breaking through the work. The drill rod unit 7 returns to the top end of the stroke after completing the hole, due to stop 45 finally contacting lever 46 and causing the normal reversal as heretofore explained. In the meantime lever 68 remains in the decreased feed position. A new piece is placed in the fixture of the machine ready for drilling, and the operator starts the cycle in the normal manner. Lever 81 is located in the proper vertical position relative to stop 44 so that it contacts with 44 after the hole is started. This shifts rod 79 in the proper direction to increase the feed rate by moving lever 68 in the opposite direction. The increased feed rate is maintained until the drill is ready to finish the hole, at which time stop 45 will again contact member 80 thus repeating the cycle.

In the case of torque reversal, this may be obtained by using a hydraulic motor 82 such as shown diagrammatically in Fig. 3 for driving the drill and then making use of the power on the pressure side of the hydraulic motor so that when this pressure exceeds a predetermined amount it automatically controls the shifting of the 4-way valve 16 to reverse the drill. As we have shown diagrammatically in Fig. 3, this hydraulic motor 82 may be connected into the power line 11 of the hydraulic system by means of a conduit 83 and the return side of the hydraulic motor will be connected through the conduit 84 to the tank return line T. The inlet conduit 83 may be connected through a suitable relief valve 86 to a conduit 87 and connected into the lower end of the valve 16. When the torque between the drill and the work increases to a predetermined amount, the pressure in the intake line 83 will cause actuation of the relief valve bypassing the pressure line so as to operate the valve 16 and reverse the drill, much the same as accomplished by the hand operated valve 75 shown in Fig. 4, and without resetting any of the stops whereby drilling will be resumed again at the same point of the cycle it was interrupted.

In referring to "accumulating stop means" in the specification and claims, it will be understood that we are referring to the stop 22 which is moved progressively at each stroke to different points along the rod to control the relative successive positions at which the drill moves from rapid traverse into feed. Thus the stop 22 is accumulating in the sense that it adds up by progressive steps the distance along the control rod 7. 37 controls the distance of each individual feed of 22 but 22 controls the position at which 37 starts to move.

What we claim is:

1. A step drilling machine comprising in combination a cylinder, a piston, a piston rod connected to a drill or drills, a hydraulic circuit for delivering fluid to and from the opposite ends of said cylinder, a pump for continuously circulating liquid through the circuit, hydraulic means for moving the piston and the drill to and from the work at rapid traverse, automatically acting stop means for changing the rapid traverse into a feed rate and for controlling the position of feeding said drill into the work at progressively increasing depths, hydraulic means for controlling the length of each feed depth by measured volume displacement, hydraulic means for controlling the rate of movement during the feeding step, and independently adjustable means for regulating the clearance between the finish of the rapid traverse and the contact of the drill with the work.

2. In a step drilling machine, the combination of a cylinder, a piston, a piston rod connected therewith, a tool member connected to and movable by said piston rod, a hydraulic circuit including means for delivering fluid to and receiving fluid from the opposite ends of said cylinder to cause reciprocation of the tool relative to the work, means movable in unison with said piston rod and cooperating with a plurality of valve units for moving said piston and said tool in a series of progressively advancing reciprocating strokes in cycles, each cycle comprising a rapid traverse movement towards the work, a relatively slow feed rate movement through a portion of the work and a rapid traverse movement from the work, accumulating stop means responsive to the feed movement in each cycle for progressively increasing the depth of rapid traverse in the succeeding cycle thereby advancing the feed range, and adjustable volumetric displacement means coordinated with the operation of said valves and connected hydraulically in series with at least one of said valves for controlling the length of each feed stroke.

3. In a step drilling machine, the combination of a cylinder, a piston, a piston rod connected therewith, a tool member connected to and movable by said piston rod, a hydraulic circuit including means for delivering liquid to and receiving liquid from the opposite ends of said cylinder to cause reciprocation of the tool relative to the work, means movable in unison with said piston rod and cooperating with a plurality of valve units for modifying the flow of liquid to and from said cylinder for moving said piston and said tool in a series of progressively advancing reciprocating strokes in cycles, each cycle comprising a rapid traverse movement towards the work, a relatively slow feed rate movement through a portion of the work and a rapid traverse movement from the work, adjustable volumetric displacement means coordinated with the operation of said valves and connected hydraulically in series with at least one of said valves for controlling the duration of each feed stroke, automatically shiftable stop means cooperating with said second named means for hydraulically controlling the application of pressure for progressively advancing the feed position of the tool, and adjustable means cooperating with said second named means and last named means for regulating the clearance between the end of the rapid traverse stroke and the contact between the tool and the work.

4. A step drilling machine comprising in

combination a drill driving member, a cylinder and a piston therein, a piston rod connecting said piston to said drill, control means movable in unison with said piston rod, a hydraulic circuit
 5 for feeding liquid to and from opposite sides of said piston to cause reciprocation of the drill relative to the work, a plurality of valve means cooperating through a single operating member with said control means, and a second set of plu-
 10 rality of valves cooperating through a single member with said control means, and hydraulic means including a volumetric displacement member hydraulically controlled by said valve means for moving the piston and drill in a series of pro-
 15 gressively advancing reciprocating strokes in cycles, each cycle comprising a rapid traverse movement towards and from the work and at a predetermined relatively slow rate through the work, means for reversing the drill at the end
 20 of each feed stroke, and means for varying the feed path with each drilling step to progressively increase the depth of the drill.

5. A step drilling machine comprising in combination a drill or drills, cylinder and piston structure connected to and controlling the movement
 25 of said drill, a hydraulic circuit for delivering liquid to and from opposite ends of said cylinder, valve structure for controlling the hydraulic movement of said piston and said drill or drills
 30 in a series of progressively advancing reciprocating strokes in cycles, each cycle comprising rapid traverse, feed and return rapid traverse strokes, accumulating stop means responsive to the move-
 35 ment of said drill through one feed stroke to determine the position of the next feed stroke for controlling the operation of said valves for hydraulically controlling the feeding of liquid to and from said cylinder to feed said drill or drills into
 40 the work to progressively increasing depths and adjustable means for controlling the length of each feed depth by measured volume displacement.

6. A step drilling machine comprising in combination a drill or drills, cylinder and piston structure connected to and controlling the movement
 45 of said drill, a hydraulic circuit for delivering liquid to and from opposite ends of said cylinder, valve structure for controlling the hydraulic movement of said piston and said drill or drills
 50 in a series of progressively advancing reciprocating strokes in cycles, each cycle comprising rapid traverse feed and return rapid traverse strokes, accumulating stop means responsive to the movement of said drill through one feed stroke to de-
 55 termine the position of the next feed stroke for controlling the feeding of said drill into the work to progressively increasing depths, and hydraulic means for controlling the length of each feed depth by measured volume displacement.

60 7. A step drilling machine comprising in combination a drill or drills, cylinder and piston structure connected to and controlling the movement of said drill, a hydraulic circuit for delivering liquid to and from opposite ends of said cylinder,
 65 valve structure for controlling the hydraulic movement of said piston and said drill or drills in a series of progressively advancing reciprocating strokes in cycles, each cycle comprising rapid traverse feed and return rapid traverse strokes,
 70 accumulating stop means responsive to the movement of said drill through one feed stroke to determine the position of the next feed stroke for controlling the feeding of said drill into the work to progressively increasing depths, and a single
 75 volumetric displacement unit for controlling the

duration of each feed stroke and the initiation of the rapid traverse return stroke of the drill.

8. In an attachment of the character described for drill presses, the combination of a hydraulic unit for ready attachment to a drill press frame,
 5 and a piston rod carried by said attachment and connected to and controlling the movement of said drill, control means movable in unison with said piston rod, a hydraulic circuit for feeding liquid to and from opposite sides of said piston to
 10 cause reciprocation of the drill relative to the work and a plurality of valve means positioned relative to said control means so as to be operated thereby, and hydraulic means responsive to the operation of said valves and connected through
 15 a shifting valve with said piston for moving said drill in a series of progressively advancing reciprocating strokes in cycles, each cycle comprising movements towards the work in rapid traverse, into the work at a predetermined feed rate,
 20 and from the work at rapid traverse, said shifting valve being actuated by positive pressure from said plurality of valves and said last named means including means for automatically resetting the feed path in each cycle.

9. In an attachment of the character described for drill presses, the combination of a hydraulic unit for ready attachment to a drill press frame,
 and a piston rod carried by said attachment and connected to and controlling the movement of
 30 said drill, control means movable in unison with said piston rod, a hydraulic circuit for feeding liquid to and from opposite sides of said piston and a plurality of valve means positioned relative to said control means so as to be operated thereby, hydraulic means responsive to the operation of said valves for successively moving said drill
 35 in a series of progressively advancing reciprocating strokes in cycles, each cycle comprising movements towards the work in rapid traverse, into the work at a predetermined feed rate and from the work at rapid traverse, accumulating stop means responsive to the feed movement in each
 40 cycle for progressively increasing the depth of rapid traverse in the succeeding cycle and thereby advancing the feed range, and a single manually operated valve member cooperating with said accumulating stop means for resetting all parts and return the drill to the starting point at any
 45 time, and means operable for reversing the drill at any time independently of and without resetting any stops or control means whereby the drill will return to its work at the point where it was reversed when progressive step drilling is resumed.

10. A step drilling machine comprising in combination a drill or drills, cylinder and piston structure connected to and controlling the movement of said drill, a hydraulic circuit for delivering fluid to and from opposite ends of said cylinder, valve
 50 structure for hydraulically moving said piston and said drill or drills in a series of progressively advancing reciprocating strokes in cycles, each cycle comprising rapid traverse, feed and return rapid traverse strokes, accumulating stop means responsive to the feed movement in each cycle for progressively increasing the depth of said traverse in the succeeding cycle and thereby advancing the feed range, hydraulic means for controlling the length of each feed depth by measured
 55 volume displacement, and means operable for reversing the drill at any time independently of and without resetting said stop means or hydraulic means.

11. In a step drilling machine, the combina- 75

tion of a cylinder, a piston, a piston rod connected therewith, a tool member connected to and movable by said piston rod, a hydraulic circuit including means for delivering fluid to and receiving fluid from the opposite ends of said cylinder to cause reciprocation of the tool relative to the work, means movable in unison with said piston rod and cooperating with a plurality of valve units for moving said piston and said tool in a series of progressively advancing reciprocating strokes in cycles, each cycle comprising a rapid traverse movement towards the work, a relatively slow feed rate movement through a portion of the work and a rapid traverse movement from the work, adjustable means coordinated with the operation of said valves for controlling the length of each feed stroke by measured volume displacement, and means operable in combination with said second named means for changing the normal feeding of said last named means.

12. A step drilling unit comprising in combination a cylinder and piston, a drill operatively connected to and movable by the piston rod of said piston, means for rotating the drill, control means connected to and movable in unison with said piston rod, a hydraulic circuit, power means for delivering a driving liquid to said circuit under pressure, hydraulic means for moving said piston and said drill to and from said step drilling operation at rapid traverse, means automatically actuated by said control means for feeding the drill into the work to progressively increasing depths, the length of each feed step being normally controlled by hydraulic measured volume displacement, and means for varying the length of any normal predetermined feed step operable in combination with said second named means to temporarily render said measured volume displacement ineffective.

13. In a step drilling machine, the combination of a cylinder, a piston, a piston rod connected therewith, a tool member connected to and movable by said piston rod, a hydraulic circuit including means for delivering fluid to and receiving fluid from the opposite ends of said cylinder to cause reciprocation of the tool relative to the work, means movable in unison with said piston rod and cooperating with a plurality of valve units for moving said piston and said tool in a series of progressively advancing reciprocating strokes in cycles, each cycle comprising a rapid traverse movement towards the work, a relatively slow feed rate movement through a portion of the work and a rapid traverse movement from the work, adjustable means coordinated with the operation of said valves for controlling the length of each feed stroke, and means operating in combination with said second named means for slowing down the feed rate at the beginning and towards the end of the complete drilling operation.

14. A step drilling machine comprising in combination a drill or drills, cylinder and piston structure connected to and controlling the movement of said drill, a hydraulic circuit for delivering fluid to and from opposite ends of said cylinder, valve structure for hydraulically moving said piston and said drill or drills in a series of progressively advancing reciprocating strokes in cycles, each cycle comprising rapid traverse, feed and return rapid traverse strokes, accumulating stop means responsive to the movement of said drill through one feed stroke to determine the position of the next feed stroke for control-

ling the feeding of said drill into the work to progressively increasing depths, and means responsive to the complete path of movement of the drill and independently of said accumulating stop means for slowing down the feed rate of the drill at the beginning and towards the end of the actual drilling operation.

15. A step drilling unit comprising in combination a cylinder and piston, a drill operatively connected to and movable by the piston rod of said piston, control means movable in unison with said piston rod, a hydraulic circuit for feeding liquid to and from opposite sides of said piston to cause reciprocation of the drill relative to the work, a plurality of valve means positioned relative to said control means so as to be operated thereby, hydraulic power means for rotating said drill, hydraulic means responsive to the operation of said valves for moving said drill in a series of progressively advancing reciprocating strokes in cycles, each cycle comprising movement toward the work in rapid traverse, into the work at a predetermined feed rate and from the work at rapid traverse, accumulating stop means carried by said control means and responsive to the feed movement in each cycle for advancing the range in each feed stroke to progressively increase the depth of the drill, and means responsive to a predetermined torque between the drill and the work for reversing the drill.

16. A step drilling unit comprising in combination a cylinder and piston, a drill operatively connected to and movable by the piston rod of said piston, control means movable in unison with said piston rod, a hydraulic circuit for feeding liquid to and from opposite sides of said piston to cause reciprocation of the drill relative to the work, a plurality of valve means positioned relative to said control means so as to be operated thereby, hydraulic power means for rotating said drill, hydraulic means responsive to the operation of said valves for moving said drill in a series of progressively advancing reciprocating strokes in cycles, each cycle comprising movement toward the work in rapid traverse, into the work at a predetermined feed rate and from the work at rapid traverse, accumulating stop means carried by said control means and responsive to the feed movement in each cycle for advancing the range in each feed stroke to progressively increase the depth of the drill, and means including both manual means and means responsive to a predetermined torque between the drill and the work for reversing the drill at any time independently of and without resetting accumulating stops.

17. A step drilling unit comprising in combination a cylinder and piston, a drill operatively connected to and movable by the piston rod of said piston, control means movable in unison with said piston rod, a hydraulic circuit for feeding liquid to and from opposite sides of said piston to cause reciprocation of the drill relative to the work, a plurality of valve means positioned relative to said control means so as to be operated thereby, hydraulic power means for rotating said drill, hydraulic means responsive to the operation of said valves for moving said drill in a series of progressively advancing reciprocating strokes in cycles, each cycle comprising movement toward the work in rapid traverse, into the work at a predetermined feed rate and from the work at rapid traverse, accumulating stop means carried by said control means and

responsive to the feed movement in each cycle for advancing the range in each feed stroke to progressively increase the depth of the drill, means responsive to a predetermined torque between the drill and the work for reversing the drill, and means responsive to the final drilling step for automatically resetting all stops and controls at the finish of the drilling operation.

18. A step drilling unit comprising in combination a cylinder and piston, a drill operatively connected to and movable by the piston rod of said piston, control means movable in unison with said piston rod, a hydraulic circuit for feeding liquid to and from opposite sides of said piston to cause reciprocation of the drill relative to the work, a plurality of valve means positioned relative to said control means so as to be operated thereby, hydraulic power means for rotating said drill, hydraulic means responsive to the operation of said valves for moving said drill in a series of progressively advancing reciprocating strokes in cycles, each cycle comprising movement toward the work in rapid traverse, into the work at a predetermined feed rate and from the work at rapid traverse, accumulating stop means carried by said control means and responsive to the feed movement in each cycle for advancing the range in each feed stroke to progressively increase the depth of the drill, means including both manual means and means responsive to a predetermined torque between the drill and the work for reversing the drill at any time independently of and without resetting accumulating stops, and means responsive to the final drilling step for automatically resetting all stops and controls at the finish of the drilling operation.

19. In a step drilling machine, the combination of a cylinder, a piston, a piston rod connected therewith, a drill member connected to and movable by said piston rod, a hydraulic circuit including means for delivering fluid to and receiving fluid from the opposite ends of said cylinder to cause reciprocation of the tool relative to the work, hydraulic means for rotating said drill, means movable in unison with said piston rod and cooperating with a plurality of valve units for moving said piston and said tool in a series of progressively advancing reciprocating strokes in cycles, each cycle comprising a rapid traverse movement towards the work, a relatively slow feed rate movement through a portion of the work and a rapid traverse movement from the work, means coordinated with the operation of said valves for controlling the length of each feed stroke, and means responsive to a predetermined torque between the drill and the work for reversing the drill at any time independently of and without resetting any valves or control means whereby the drill will return to its work at the point of reversal.

20. In a step drilling machine, the combination of a cylinder, a piston, a piston rod connected therewith, a drill member connected to and movable by said piston rod, a hydraulic circuit including means for delivering fluid to and receiving fluid from the opposite ends of said cylinder to cause reciprocation of the tool relative to the work, hydraulic means for rotating said drill, means movable in unison with said piston rod and cooperating with a plurality of valve units for moving said piston and said tool in a series of progressively advancing reciprocating strokes in cycles, each cycle comprising

a rapid traverse movement towards the work, a relatively slow feed rate movement through a portion of the work and a rapid traverse movement from the work, means coordinated with the operation of said valves for controlling the length of each feed stroke, means responsive to a predetermined torque between the drill and the work for reversing the drill at any time independently of and without resetting any valves or control means whereby the drill will return to its work at the point of reversal, and means responsive to the final drilling step for automatically resetting all stops and controls at the finish of the drilling operation.

21. In a machine tool having a tool holder, hydraulic means for advancing and retracting said holder, a hydraulic circuit for delivering fluid to and from said means, a pump for continuously circulating liquid through the circuit, hydraulic control means for effecting advancing and retracting of the tool holder at rapid traverse, automatically acting stop means for changing the rapid traverse of the tool holder into a feed rate and for controlling the progressive positioning of the tool holder relative to the work at each successive stroke, hydraulic means for controlling the amount of movement during the operation of each progressive feed rate by measured volume displacement, and hydraulic means connected in series with said last named means for controlling the rate of movement during the feeding step.

22. In a machine tool having a tool holder, hydraulic means for advancing and retracting said holder, a hydraulic circuit for delivering fluid to and from said means, a pump for continuously circulating liquid through the circuit, hydraulic control means for effecting advancing and retracting of the tool holder at rapid traverse, automatically acting stop means for changing the rapid traverse of the tool holder into a feed rate and for controlling the progressive positioning of the tool holder relative to the work at each successive stroke, hydraulic means for controlling the amount of movement of each progressive feed into the work by measured volume displacement, hydraulic means for controlling the rate of movement during the feeding step, and independently adjustable means for regulating the clearance between the finish of the rapid traverse and the contact of the tool with the work.

23. In a machine tool having a tool holder, hydraulic means for advancing and retracting said holder, a hydraulic circuit for delivering fluid to and from said means, a pump for continuously circulating liquid through the circuit, hydraulic control means for effecting advancing and retracting of the tool holder at rapid traverse, automatically acting stop means for changing the rapid traverse of the tool holder into a feed rate and for controlling the progressive positioning of the tool holder relative to the work at each successive stroke, hydraulic displacement means connected with a shift valve for controlling the amount of movement of each progressive feed into the work and time of return, and hydraulic means for controlling the rate of movement during the feeding step.

24. In a machine tool having a tool holder, cylinder and piston structure connected to and controlling the movement of said tool holder, a hydraulic circuit for delivering liquid to and from opposite ends of said cylinder, valve structure for controlling the hydraulic movement of said piston and said tool holder in a series of pro-

gressively advancing reciprocating strokes in cycles, each cycle comprising feed and return rapid traverse strokes, and a single volumetric displacement unit for controlling the amount of each progressive advance into the work and the initiation of the rapid return stroke.

25. In a machine tool having a tool holder, cylinder and piston structure connected to and controlling the movement of said tool holder, a hydraulic circuit for delivering liquid to and from opposite ends of said cylinder, valve structure for controlling the hydraulic movement of said piston and said tool holder in a series of progressively advancing reciprocating strokes in cycles, each cycle comprising feed and return rapid traverse strokes, and an adjustable hydraulic displacement unit adapted to be connected in series with liquid exhausted from said cylinder at the start of each feed stroke for controlling the amount of each progressive advance.

26. In a machine tool having a tool holder, hydraulic means including piston and cylinder for advancing and retracting said holder, reversing and speed control means for said holder, and a hydraulic circuit hydraulically connected to said reversing and speed control means for delivering fluid to and from the opposite ends of said cylinder,

the combination therewith of hydraulic displacement means connected into said circuit and adapted to be connected in series with liquid exhausted from said cylinder at the start of each feed stroke and operable by measured volume displacement to progressively advance the working position of the tool holder a predetermined distance at each stroke.

27. In a machine tool having a tool holder, hydraulic means including piston and cylinder for advancing and retracting said holder, reversing and speed control means for said holder, and a hydraulic circuit hydraulically connected to said reversing and speed control means for delivering fluid to and from the opposite ends of said cylinder, the combination therewith of hydraulic displacement means connected into said circuit and adapted to be connected in series with liquid exhausted from said cylinder at the start of each feed stroke and operable by measured volume displacement to progressively advance the working position of the tool holder a predetermined distance at each stroke, and means for varying said measured volume displacement to control the amount of said advancement.

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