Aug. 18, 1942. E. J. HIRVONEN 2,293,464

DRILLING MACHINE

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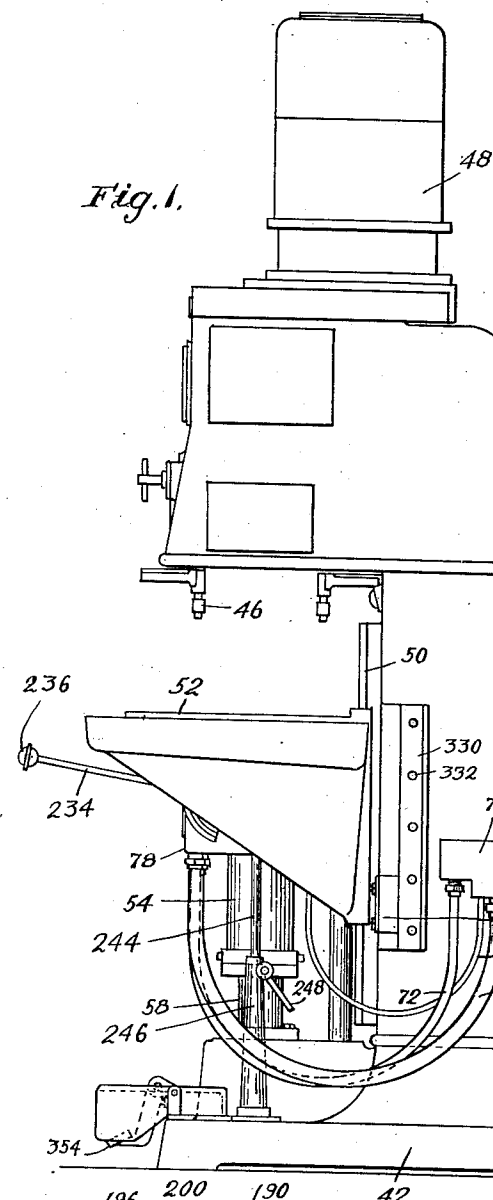


Fig. 1.

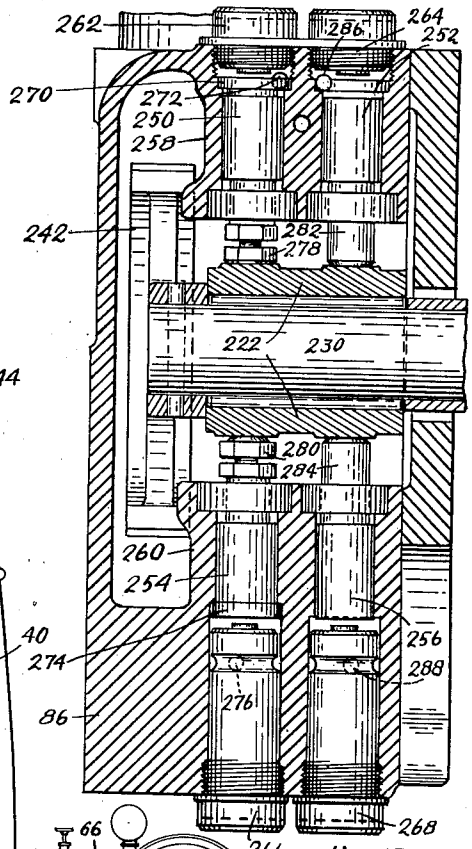
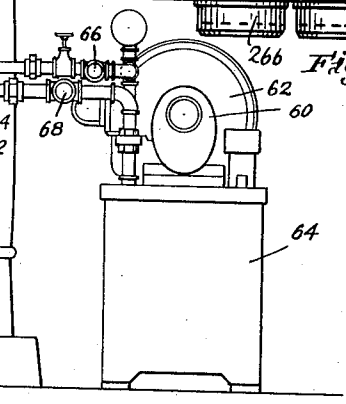


Fig. 13.



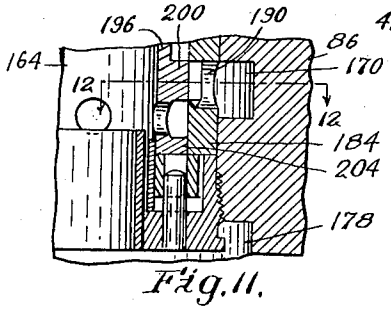


Fig. 11.

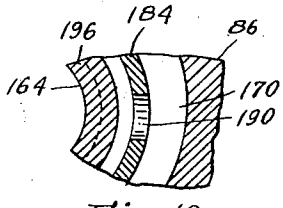


Fig. 12.

Inventor:
Eric J. Hirvonen
by
Atty

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DRILLING MACHINE

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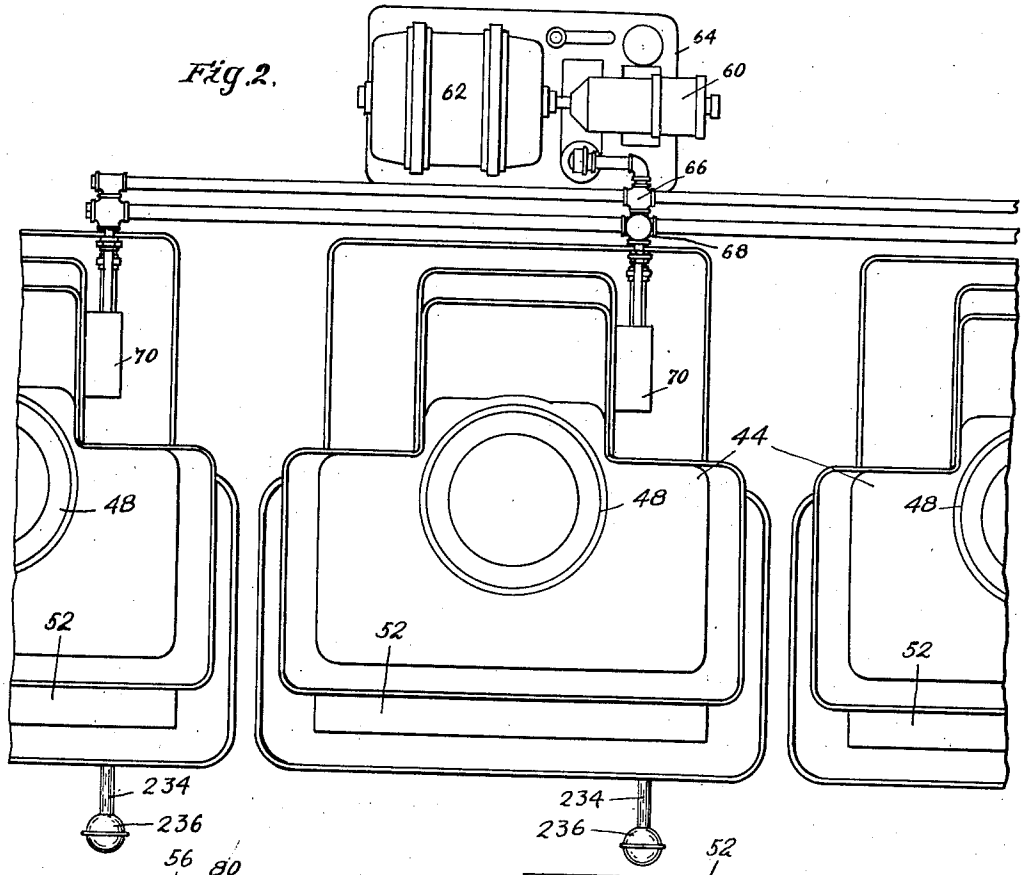
Fig. 2.



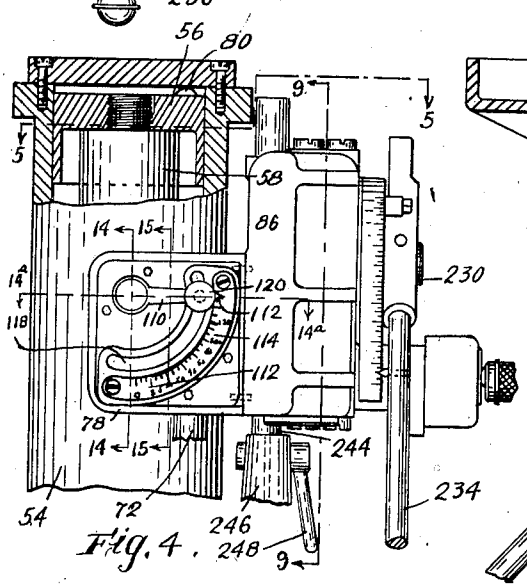


Fig. 4.

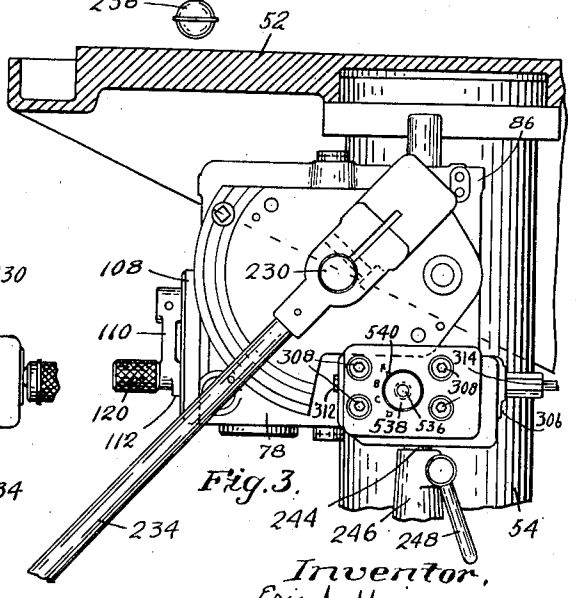


Fig. 3.

Inventor,
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by Lemmon & Lemmon Atty

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DRILLING MACHINE

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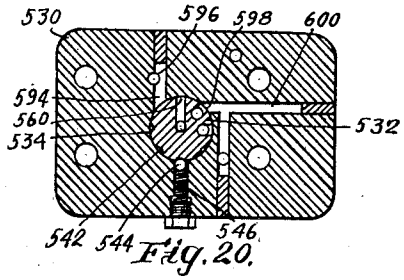

Fig. 20.

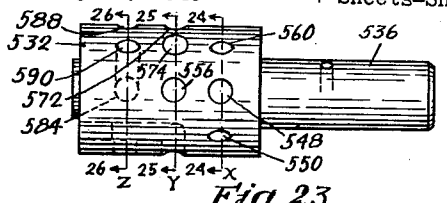

Fig. 23.

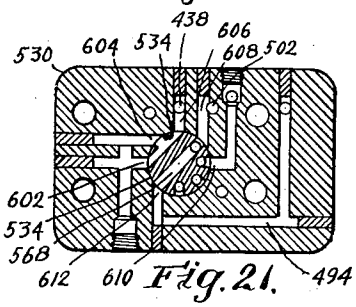

Fig. 21.

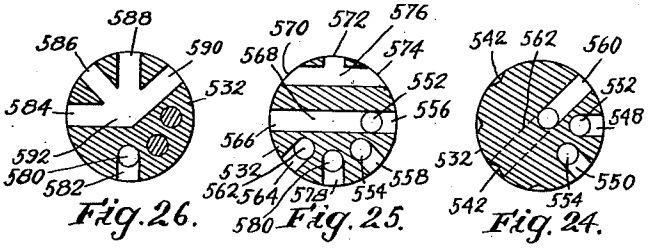

Fig. 26. Fig. 25. Fig. 24.

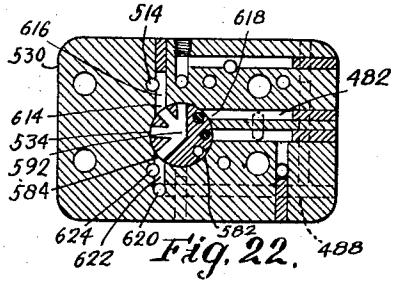

Fig. 22.

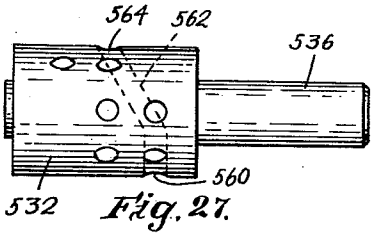

Fig. 27.

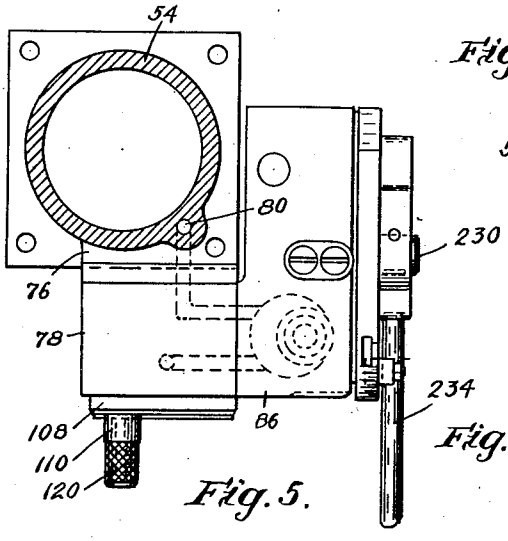

Fig. 5.

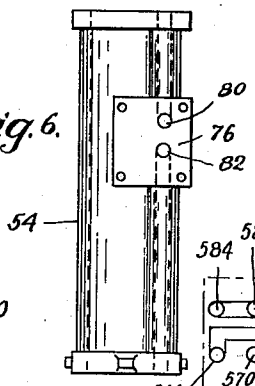

Fig. 6.

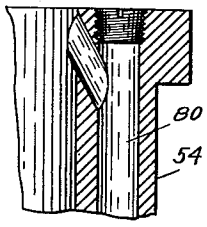

Fig. 8.

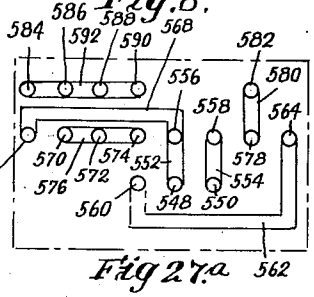

Fig 27a

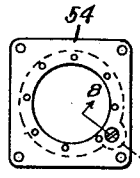

Fig. 7.

Inventor.
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atty

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DRILLING MACHINE

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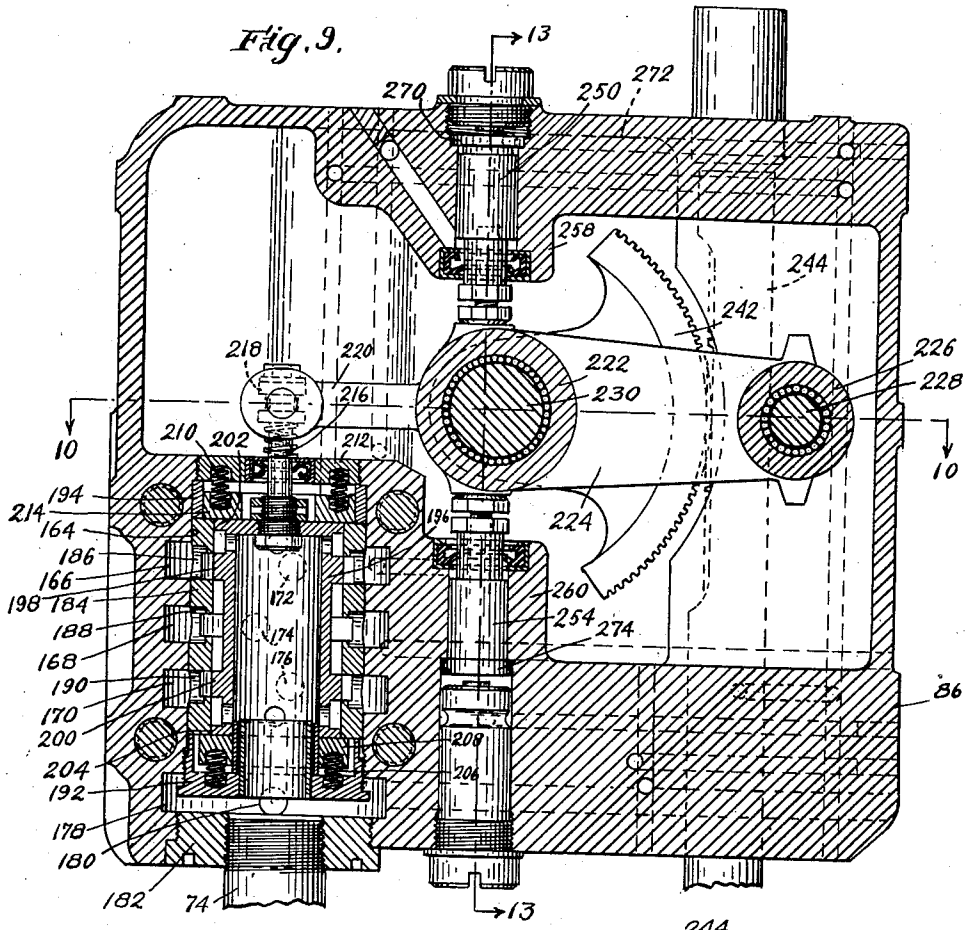
Fig. 9.



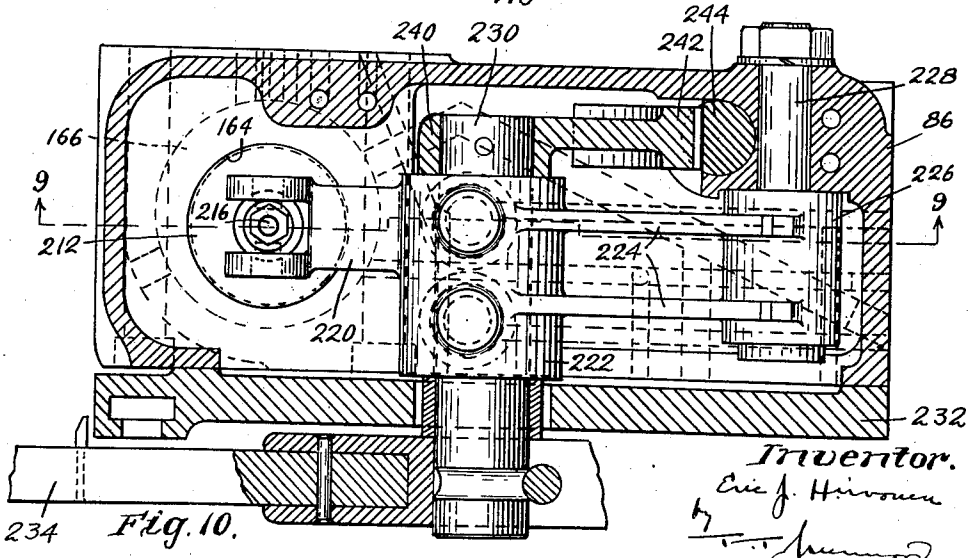


Fig. 10.

Inventor.
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Atty

Aug. 18, 1942. E. J. HIRVONEN 2,293,464

DRILLING MACHINE

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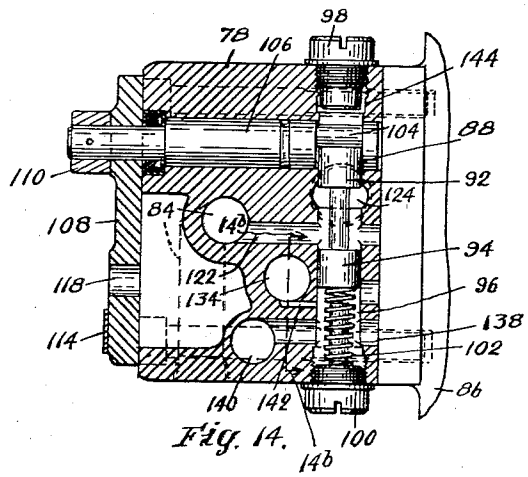


Fig. 14.

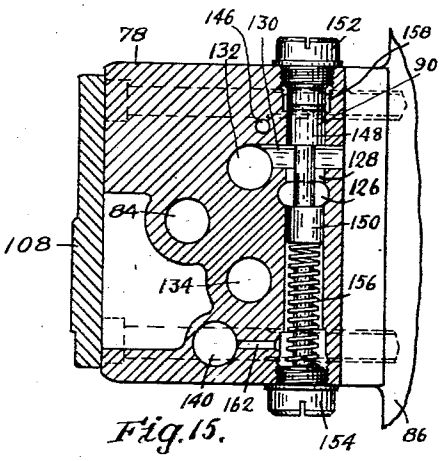
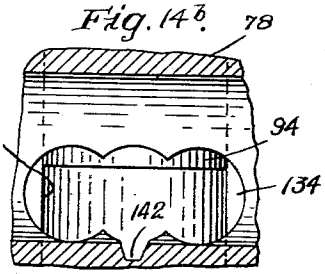


Fig. 15.

Fig. 14b.



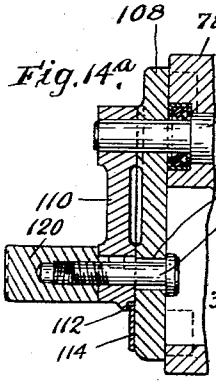


Fig. 14a.

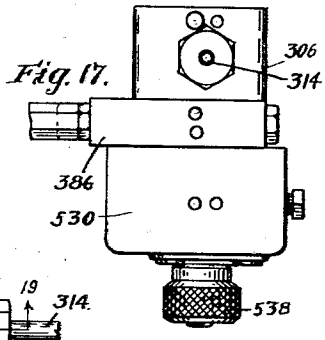


Fig. 17.

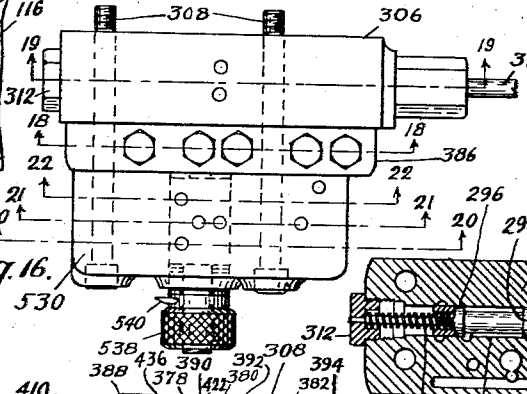


Fig. 16.

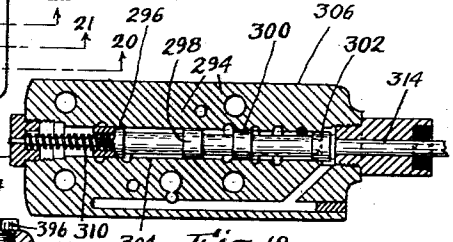


Fig. 19.

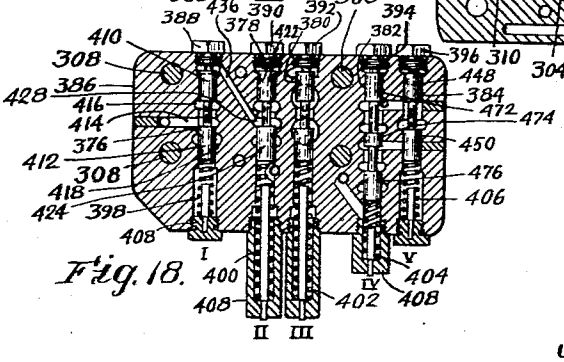


Fig. 18.

Inventor.
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by [illegible] Atty

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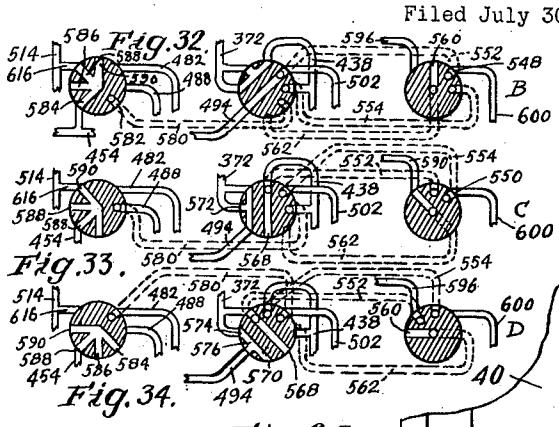
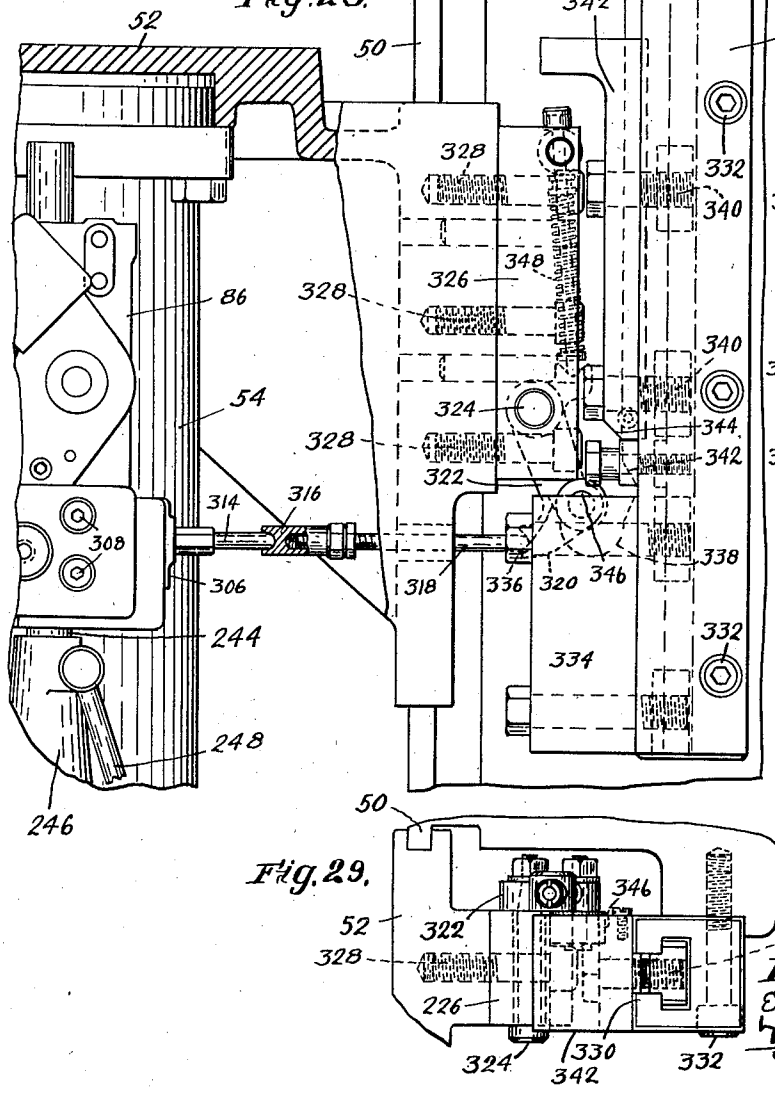


Fig. 28.



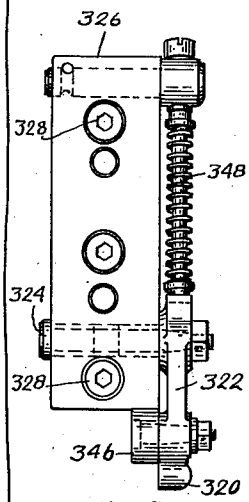


Fig. 30.

Fig. 29.

Inventor.
Eric J. Hirvonen
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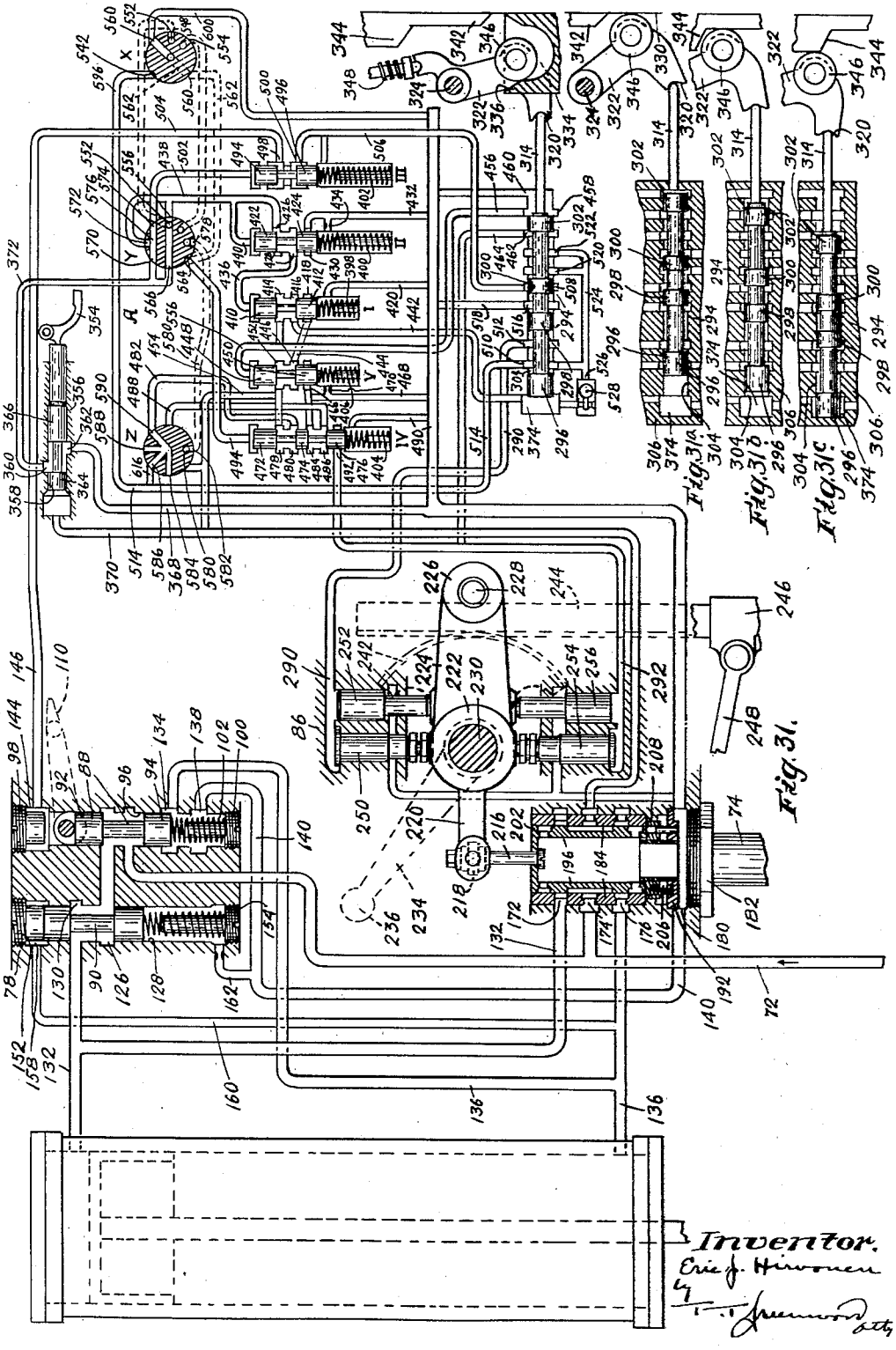

Fig. 31.

Fig. 31a.

Fig. 31b.

Fig. 31c.

Inventor.
Eric J. Hirvonen
by T. J. Hammond Atty

Patented Aug. 18, 1942 2,293,464

UNITED STATES PATENT OFFICE

2,293,464

DRILLING MACHINE

Eric J. Hirvonen, Worcester, Mass., assignor to Leland-Gifford Company, Worcester, Mass., a corporation of Massachusetts

Application July 30, 1940, Serial No. 348,389

49 Claims. (Cl. 77—32)

This invention relates to a hydraulic drilling machine having provision for automatic, as well as manual, control of the rate and direction of relative movement between the drill and the work.

In the present machine, herein shown as a multiple spindle drill, it is more convenient to move the work supporting table relatively to the drills, rather than the drills to the work.

One of the objects of the present invention is the provision of a hydraulically operated drill having a hydraulic motor, as a cylinder and piston, for moving the work toward and away from the drill, and control mechanism so arranged that the work supporting table can be caused to operate automatically in different ways or cycles, including complete manual control of the speed, direction of movement and position, as determined by the setting of suitable cycle selecting valve mechanism.

The hydraulically operated drilling machine of the present invention is so arranged that it can be operated like an entirely mechanical hand operated sensitive drilling machine, where the direction and rate of movement of the work supporting table and the pressure of the drill on the work is controlled by a suitable hand lever, the work following the movement of the hand lever at a proportional speed and exerting pressure on the drill in proportion to the manual pressure on the hand lever.

The machine is also arranged to operate on several cycles as follows:

A. A fast approach from a neutral or retracted position to a stop position close to the drill in response to the depression of a foot pedal, and then a slow feed against the drill upon release of the pedal and an automatic retraction from the drill after the full depth of hole has been drilled. Depression of the pedal during any advanced position of the work effects the automatic retraction of the work to the neutral or retracted position.

B. An automatic cycle consisting of a fast approach to the drill, a slow feed against the drill without any stop at the end of the fast approach stroke, and a rapid retraction to the neutral position, the cycle being initiated by the depression of the foot pedal and the movement being reversed at any intermediate advanced position of the work by a subsequent depression of the pedal.

C. A continuous repetition of the automatic cycle consisting of a rapid advance to the drill, a slow feed against the drill, a rapid traverse to a position clearing the drill, and a repetition of the aforesaid initiated by depressing the pedal and continued by holding the pedal depressed, emergency return being effected by the release, the depression and subsequent release of the pedal.

D. Purely hand feed.

The various cycles are selected and are caused to be rendered operative by appropriate cycle selecting valve mechanism. A machine thus arranged constitutes a further object of the present invention.

Another object of the invention is generally to improve the operation of hydraulic drilling machines.

This application is a continuation in part of my application Serial No. 237,510, filed October 28, 1938, wherein is shown and claimed a hydraulic drilling machine arranged for purely manual control of the speed and direction of movement of the drill and pressure of the drill on the work.

Fig. 1 is a side elevation of a hydraulic drilling machine and hydraulic fluid supply unit embodying the present invention.

Fig. 2 is a plan view of several of the drilling machine units of Fig. 1, arranged in line, and taking hydraulic fluid from a common supply.

Fig. 3 is a side elevation of the table reciprocating hydraulic cylinder and piston and control mechanism of Fig. 1, part of the movable work supporting table being broken away.

Fig. 4 is a front elevation of the mechanism of Fig. 3.

Fig. 5 is a plan view of the mechanism of Fig. 3 taken along line 5—5 of Fig. 4.

Fig. 6 is a side elevation of the hydraulic cylinder.

Fig. 7 is a plan view of the cylinder.

Fig. 8 is a sectional detail taken along line 8—8 of Fig. 7, and illustrating particularly the arrangement of oil passages.

Fig. 9 is an enlarged sectional detail of the manual control valve and its associated mechanism, taken along lines 9—9 of Figs. 4 and 10.

Fig. 10 is a section taken along line 10—10 of Fig. 9.

Fig. 11 is an enlarged sectional detail of the lower end part of the manual control valve taken at right angles to the section of Fig. 9.

Fig. 12 is a sectional detail taken along line 12—12 of Fig. 11.

Fig. 13 is a section taken along line 13—13 of Fig. 9, and illustrating particularly the hydraulically-operated valve holding and setting plungers.

Fig. 14 is a section through the feed-rate con-

trolling valve, taken along line 14—14 of Fig. 4, the valve being illustrated in an open position thereof.

Fig. 14a is a sectional detail of the manual valve setting lever of Fig. 14, taken along line 14a—14a of Fig. 4.

Fig. 14b is a detail illustrating the arrangement of the exhaust oil port of the feed-rate valve, viewed from the left hand end of the feed-rate valve block of Fig. 14.

Fig. 15 is a sectional view taken along line 15—15 of Fig. 4, and illustrating particularly the governing valve for securing an unvarying rate of movement of the table regardless of pressure variations between the work and the drill.

Fig. 16 is a plan view of the valve block assembly of Figs. 3 and 4, containing the cycle selecting valves, the selector controlled switching valves and the work-position-controlled reversing valve.

Fig. 17 is an end view of the valve block assembly of Fig. 16.

Fig. 18 is a sectional detail taken along line 18—18 of Fig. 16, and illustrating the switching valves.

Fig. 19 is a sectional view taken along line 19—19 of Fig. 16, and illustrating the reversing valve.

Fig. 20 is a section through the cycle selector valve block taken along line 20—20 of Fig. 16.

Fig. 21 is a section taken along line 21—21 of Fig. 16.

Fig. 22 is a section taken along line 22—22 of Fig. 16.

Fig. 23 is a side elevation of the cycle selecting valve.

Figs. 24, 25 and 26 are sections taken along lines 24—24, 25—25, and 26—26, respectively, of Fig. 23, and corresponding with Figs. 20, 21 and 22, respectively, which sections are hereinafter termed the X, Y and Z sections of the selector valve.

Fig. 27 is a side elevation of the selector valve with the valve in a partially rotated position with respect to the position illustrated in Fig. 23 to show an internal port-interconnecting passage.

Fig. 27a is a plan lay-out of the passages of the cycle selector valve of Fig. 23.

Fig. 28 is a side elevation of the hydraulic cylinder, table, valve mechanism and supporting column with the side web of the table broken away to illustrate the valve mechanism and the cam mechanism carried by the column for controlling the reversing valve to control the beginning of the slow feed advance and the amount of feed advance and retraction of the table.

Fig. 29 is an end view of the cam operated reversing valve controlling mechanism of the cylinder and table, looking up in Fig. 28.

Fig. 30 is a plan view of the cam operated reversing valve controlling mechanism, looking to the left in Fig. 28.

Fig. 31 is a diagram of the hydraulic circuits of the apparatus, with the selector valve set for the performance of cycle A.

Figs. 31a, 31b and 31c are respectively fast, advance, feed and retraction positions of the reversing valve of Fig. 31.

Figs. 32, 33 and 34 represent successive positions assumed by the X, Y and Z sections of the cycle selector valve for cycles B, C and D.

The hydraulic drilling machines embodying the present invention includes a vertical column 40 rising from a supporting base 42 and carrying at the upper part thereof a housing 44 which supports a plurality of drill spindles 46 that are adjustable as to their position with respect to each other and are driven by an electric motor 48 common to all spindles. The column under the drill spindle is provided with vertical ways 50 on which a work supporting table 52 is vertically movable by hydraulic mechanism including a vertical hydraulic cylinder 54 disposed under and fixed to the table and a piston 56, Fig. 4, operative within the cylinder and fixed to the upper end of a vertical piston rod 58 bolted to the base 42. As thus arranged, the piston and piston rod are fixed and remain stationary and the cylinder and table reciprocate.

The cylinder receives oil under pressure through control mechanism, later to be described, from a constant pressure oil supply comprising a gear pump 60 driven by a constant speed motor 62, the pump and motor being mounted on the cover of an oil tank 64. The pressure supply unit is intended to maintain an ample supply of oil under constant pressure at all times when operating. The particular unit herein employed is now well known in the art and is illustrated in my joint patent with Benjamin S. T. Bishop No. 1,905,133, issued April 25, 1933.

Oil under pressure is delivered from the supply unit into a pressure manifold 66 to a battery of similar hydraulic drilling machines and exhaust oil from the machines is delivered to a manifold 68 from whence the oil returns into the tank. The high pressure and exhaust oil manifolds are connected to a junction box 70 associated with each machine where the high pressure and the exhaust oil pass through flexible pipes or hose 72 and 74, respectively, between the junction box to the valve mechanism carried by and movable with the table.

The hydraulic cylinder 54, see especially Figs. 6, 7 and 8, is provided intermediate its ends with a pad 76 to the face of which a feed-rate controlling valve block 78 is bolted. The cylinder has upper and lower oil passages or ducts 80 and 82, respectively, which open into the face of the pad and register with appropriate passages in the valve block. The upper and lower ends of the ducts open into the upper and lower ends of the cylinder, as illustrated in Fig. 8 respectively above and below the piston at its extreme positions.

The valve block 78 has a high pressure oil passage 84 therein which has one opening in the lower face of the block where it connects with the high pressure hose or flexible conduit 72 and has another opening in the right hand side face of the block where it communicates with a hand-controlled valve casing 86. The valve block 78, see Figs. 4, 14, 15 and 31, contains a speed or feed-rate setting valve 88 by which the cutting speed of the table is set and a governing valve 90 which maintains the cutting speed uniform regardless of variations in pressure between the drill and the work at any speed as set by the speed setting valve 88.

The speed setting valve 88 is of the piston type and includes two spaced pistons 92 and 94, Fig. 14, operating in a vertical passage or cylinder 96, the ends of the passage being closed by screws 98 and 100. A spring 102 acts endwise on the lower end of the valve to press the upper end against an eccentric part 104 of a shaft 106 journalled horizontally in the valve block and extended through the cover 108 thereof and having a manually-engageable arm 110 fixed to the outer end thereof. The free end of said arm

has an indicating projection 112 which travels over an arcuate speed indicating scale 114 carried by the cover plate. The arm 110 can be clamped in any adjusted position by means of a bolt 116 which passes through the end of the arm and is free for axial movement therein but is held against rotation. The inner end part of the bolt operates in an arcuate slot 118 of the cover plate and has a head which overlies the slot. Thus by tightening up the finger grip member 120, which is screw-threaded on the bolt, the arm can be clamped to the cover plate in any set position. It will be apparent that the swinging of the arm causes the eccentric part 104 of the shaft 106 to rise and fall and thereby varies the vertical position of the feed-rate setting valve 88.

The valve cylinder 96 is provided with a port 122 which opens into the high pressure duct 84 so that pressure oil is always maintained between the valve pistons 88, 94. The upper valve piston 88 controls the flow of high pressure oil from the valve cylinder 96 through the port 124 by cutting off more or less of the area of the port as determined by the setting of the valve under control of the shaft 106, or by completely closing said port by hydraulic operation as will be explained hereinafter. The port 124 is in line with and communicates with the port 126 in the valve cylinder 128 of the governing valve 90 from whence oil ultimately flows into the top of the cylinder 54 through an upper port 130 and a duct 132, see also Fig. 31. The lower valve piston 94 of the feed regulating valve is arranged to control the effective opening of a lower duct 134 which receives exhaust oil from the bottom end of the cylinder, the oil coming from a duct 136 and passing, as throttled by the valve, out of the valve cylinder through a lower port 138 into an exhaust duct 140 and thence to drain. The outlet duct 134 is provided with a small notch 142, see Figs. 14, 14b, in its lower wall so that when the lower valve piston 94 moves downwardly to close the port 134 either by manual operation of the arm 110 or by hydraulic operation, the outflow of oil from the bottom of the cylinder is not suddenly stopped but is throttled in a more or less gradual manner.

The feed valve can be moved downwardly independently of direct manual control by the introduction of pressure oil into the cylinder chamber 144 above the top piston 88 through a duct 146 under control of the cycle selecting valve apparatus hereinafter to be described.

The speed governing valve 90 has two valve pistons 148 and 150 operating in the valve cylinder 128, the cylinder being closed at the top and bottom ends by screws 152, 154, respectively. A compression spring 156 is in the cylinder and bears against the lower end of the valve to maintain it normally in raised position against the upper screw 152. The incoming oil, flowing at a rate determined by the setting of the feed valve 88, enters the valve cylinder 128 through the port 126 and passes out of the cylinder through the upper port 130 and through the duct 132 into the top of the cylinder, as has been described. Oil is introduced into the upper cylinder chamber 158 through a duct 160, see Fig. 31, communicating with the duct 136 so that the back pressure oil in the bottom of the cylinder influences the setting of the governing valve 90 to cause the governing valve to increase the throttling effect on the inflowing oil in accordance with the increase of back pressure of the outflowing oil. With the arrangement of the speed setting and governing valves, the movement of the table is uniform for any setting of the speed valve regardless of variations in pressure between the work and the drill. The fundamental principle of operation of these valves is not herein novel as it is described, for instance, in my Patent No. 2,073,518, dated March 9, 1937, although the manner of the manual setting of the speed valve is herein novel. The lower end of the governing valve cylinder 128 is connected to the exhaust duct 140 through a restricted passage 162 which serves to prevent sudden movements of the valve.

The speed setting and governing valves are operative for parts of the automatic cycles when the machine is set for automatic operation but are rendered inoperative when the machine is set for entirely manual operation, as will presently appear.

The control of the oil flow into and out of the upper and lower ends of the hydraulic cylinder is also under control of main or master valve mechanism located within the valve block 86, this mechanism being susceptible of purely manual operation and also being susceptible of hydraulic control. Said valve mechanism, see especially Figs. 9, 10, 11, 12 and 31, includes a valve cylinder 164 having upper, intermediate and lower annular ports 166, 168 and 170, respectively, which communicate through upper, intermediate and lower ducts 172, 174, 176, respectively, with the ducts 132, 84 and 136, respectively, of the valve block 78. Thus the intermediate port 168 is constantly under high pressure oil from the oil supply and the upper port 166 is in constant communication with the upper end of the cylinder and the lower port 170 is in constant communication with the lower end of the cylinder. The valve cylinder also has a lowermost port 178 which communicates through a duct 180 with the exhaust duct 140 of the valve block 78, by which duct the exhaust oil from the speed and governing valves passes to the drain. The bottom end of the valve cylinder is closed by a plug 182 through the bottom of which the drain hole 74 communicates.

The valve cylinder 164 has a valve sleeve 184 fixed therein provided with upper, intermediate and lower ports 186, 188 and 190, which register with respective ports 166, 168 and 170. The valve sleeve is clamped in place by a disc 192 which is screw-threaded into the lower end of the valve cylinder and presses the sleeve against a spacing ring 194 seated on a shoulder in the upper end of the cylinder.

A hollow valve 196 reciprocates vertically within the sleeve and has upper and lower lands 198 and 200, respectively, which normally confront and seal the ports 186 and 190 of the valve sleeve. The valve also has end lands 202 and 204 which provide exhaust passages between them and the adjacent lands 198, 200, which passages open to the interior of the valve. Thus upward displacement of the valve opens the port 186 to receive high pressure oil from the intermediate port 188 to effect the upward movement of the work supporting table. At the same time, the valve opens the lower port 190 to discharge oil from the bottom of the cylinder into the interior of the valve where the oil runs into the drain 74. Depression of the valve from the mid position causes high pressure oil to be admitted into the lower end of the cylinder to retract the work supporting table and causes exhaust oil to flow to waste from the

upper end of the cylinder. When the valve cylinder is in a partial port open position the flow of oil through the ports is partially restricted resulting in a reduced rate of movement of the table.

The valve is held in mid position by a series of short compression springs **206** which bear between the threaded ring **192** and a disc **208** which overlies the lower end of the valve and is seated thereon and also normally on the valve sleeve. Similar compression springs **210** are located above the valve and bear against a disc **212** screw-threaded into the upper end of the cylinder and a floating disc **214** normally seated on the upper end of the valve and the upper end of the valve sleeve. With this arrangement, the valve is normally held in the mid position illustrated and movement of the valve in either direction is resisted by one or the other set of springs. The springs are preferably short so that they offer increased resistance to increased displacement of the valve.

The valve is provided with an axially located valve stem **216** which extends through the disc **212** and has an annularly grooved collar **218** at its upper end in the grooves of which are located pins of an arm **220** which outstands from a hub **222**. The hub is carried at the ends of a pair of parallel arms **224**, the other ends of which are connected integrally through a sleeve **226** journalled freely by anti-friction bearings on a stud **228** fixed in the valve housing **86**. The arm **220**, hub **222** and arms **224** constitute a lever for operating the valve. Thus vertical movement of the lever about the shaft **228** causes corresponding movement of the valve **196**.

The movements of the valve are controlled hydraulically and also independently manually. The manual control of the setting of the valve includes a shaft **230** journalled freely by anti-friction bearings in the hub **222** and projecting loosely through the front cover plate **232** of the valve housing. The projecting end of the shaft is fixed to the end of a control handle **234** projecting forwardly under the table and terminating in a knob **236**. Thus by raising and lowering the handle the shaft **230** is rotated in opposite directions.

The inner end of the shaft passes through and is fixed in the hub **240** of a gear sector **242**, the teeth of which mesh with the teeth of a vertical rack **244** slidable through the housing **86**. The rack passes through the housing and the lower end part thereof is located within a standard **246**, see Fig. 1, fixed to the base **42** of the pedestal. The rack is slidable in the standard **246** or it can be clamped immovably with respect thereto by means including the clamping lever **248**. For automatic operation of the machine the rack is free from the standard and can reciprocate with the table relatively thereto. For purely manual operation of the machine the rack is clamped to the standard so that the valve housing **86** reciprocates relatively thereto.

Bearing in mind that the feed-rate and governing valve are not operated when the device is arranged for purely manual operation, either by the setting of the cycle selecting valve presently to be described, or by the setting of the feed valve in closed position, the manual operation is essentially as follows:

With no pressure on the operating handle **234**, the valve **196** is maintained in closed position by the upper and lower sets of springs and hence ducts leading from the top and bottom ends of the cylinder will be closed and the table thus is locked hydraulically in position. If now the handle **234** is raised upwardly the gear sector **242** is caused to pivot on the fixed rack **244** and hence the lever system associated with the valve is raised, thereby raising the valve and letting high pressure oil flow into the upper end of the cylinder and allowing oil to escape from the lower end of the cylinder. Thus the table is caused to move upwardly. If the handle is merely moved a certain amount upwards and then stopped, the upward movement of the table causes the pivot shaft **228** of the lever system to be moved upwardly and thereby causes the lever to be pivoted in a counter-clockwise direction about the handle shaft **230**, thereby causing the valve to close and the table to become stationary in some elevated position corresponding to the displaced elevated position of the handle. If, however, the handle is moved upward in a continuous manner the table follows this movement. If the handle is moved upwardly slowly there is only a small opening of the valve cylinder ports so that oil is admitted to the upper end of the actuating cylinder and allowed to escape from the lower end relatively slowly so that the upward table movement in response to the upward handle movement is correspondingly slow. If, however, the upward movement of the handle is rapid the opening of the ports is greater and the table responds at greater speed. The downward movement of the table is accomplished in a similar manner. The springs **206**, **210** are relatively short so that their resistance to compression increases with the amount of compression. Hence the force applied to the handle is caused to increase for an increased rate of movement of the table and also for an increased resistance between the drill and the work, which drill resistance requires a greater amount of port opening to overcome. Thus the device operates like a purely mechanical sensitive drill in that the operator can feel the action of the drill through the handle. This manual operation has been described in greater detail in my above referred to co-pending application Serial No. 237,510, and need not be further described here.

In addition to purely manual operation, provision is made for hydraulic operation in an automatic cycle controlled by the position of the table and modified in certain ways. The automatic cycle consists of a fast approach of the work to the drill, a slower feed movement against the drill to a predetermined depth, and a fast retraction to a neutral or stop position.

Four modified methods of operation are herein provided.

In cycle A the automatic cycle as above described is performed except that the table comes to rest when the work is close to the drill and at the end of the fast approach stroke and does not start its feed stroke until a foot pedal is operated. The cycle is initiated by depressing and holding the pedal down until the table comes to rest with the work close to the drill and the remainder of the cycle is accomplished upon release of the pedal. The subsequent depression of the pedal at any part of the stroke gives an emergency reversal of the table.

Cycle B is the automatic cycle without the intermediate stop and is started by the depression and release of the pedal. Emergency reverse is obtained by again depressing the pedal.

In cycle C the depression and holding of the pedal in depressed position gives a continuous

repeating of the automatic cycle. The release of the pedal and then the depression and subsequent release of the pedal provides for emergency return.

Cycle D is purely hand feed.

The control of the table actuating cylinder and piston in cycles A, B and C is effected through the valve 196. Thus it is necessary that this valve be provided with hydraulically operated mechanism to move the valve from a neutral position into an upper position to secure upward movement of the table and into a lower position to secure downward movement of the table and also at times to hold the valve in neutral position.

This control of the valve is obtained by a valve holding plunger 250 and a valve setting plunger 252 located above and adapted to bear on the hub 222 of the valve lever, and a similar valve holding plunger 254 and a valve setting plunger 256 disposed under and adapted to bear on the hub 222. Said pairs of plungers are opposed to each other and are located in the cylinders of bosses 258 and 260 formed in the valve housing 86, see Figs. 9, 10, 13 and 31, the cylinders for the upper pair of plungers being open at their outer ends and closed by plugs 262, 264, and the lower cylinders being open at their lower ends and closed by the plugs 266, 268.

The valve holding plunger 250 is provided with an enlarged head 270 which engages the bottom shoulder of an enlargement of the cylinder and limits the downward movement of the plunger under influence of oil pressure in the cylinder above the head admitted through the duct 272. The lower valve holding plunger 254 is provided with a similar enlarged head 274 which limits the upward movement of the plunger under influence of oil pressure admitted under the head through the port 276.

The plunger 250 is provided with a screw 278 adjustably projected from its end and adapted to engage the hub 222 of the valve lever system. The lower plunger 254 is similarly provided with an adjustable screw 280 also adapted to engage the hub 222.

The valve setting pistons 252, 256 are provided with stems 282, 284 projected therefrom and adapted to engage the hub 222. The outer ends of the pistons are subjected to pressure oil entering their respective cylinders through ports 286, 288. The ports 272, 286 for the upper plungers 250, 252 are connected to a common duct 290, see Fig. 31, while the ports 276, 288 for the lower set of plungers 254, 256 are connected to a common duct 292. The outward movement of the plungers, particularly the valve positioning plungers 250, 254, is limited by engagement with their associated end caps or plugs 262, 266.

With the described arrangement, when both ducts 290, 292 are free from oil pressure, the valve springs 206, 210 hold the control valve in neutral position so that flow of oil into or out of the opposite ends of the actuating cylinder is prevented and hence the table remains stationary. The same result occurs when both ducts 290, 292 are under oil pressure. In this event, the plungers 250, 252 and 254, 256 are forced inwardly in opposite directions against the hub 222 and since the sets of plungers have the same area hold the valve in neutral position. If, however, the duct 290 is under oil pressure and the duct 292 is free from oil pressure, as being connected to drain 74, then the plunger 252 moves downwardly and presses the hub 252 of the valve lever against the end of the lower plunger 254 which is against its associated cap, thereby moving the valve and holding it in position to effect retraction of the table away from the drill. When the duct 290 is free from oil pressure and the duct 292 is under oil pressure then the piston 256 operates to move the hub and the valve upwardly and hold the hub pressed against the plunger 250, thereby setting the valve in position to effect the upward or advancing movement of the table.

The aforesaid control of the plungers is effected through means including a reversing valve 294, see Figs. 16, 17, 19 and 31, the setting of which is controlled partly by the position of the table and partly by pressure oil acting on the left hand end, Fig. 31, of the valve. Said reversing valve effects fast and slow advance of the table and its retraction from some advanced position to a fully retracted position.

The reversing valve 294 is of the piston type comprising four spaced and connected piston sections 296, 298, 300, 302, respectively, movable axially in a cylinder bore 304 formed in a valve block 306 of an assembly of valve blocks secured by screws 308 to the side face of the valve housing 86, as illustrated in Fig. 3. The reversing valve has a long axial bore extended inwardly from the left hand end thereof, Fig. 19, in which is located a compression spring 310 bearing against an end cap 312 of the cylinder bore to bias the valve for movement toward the right, although not for movement independently of the controlling cam mechanism, now to be described.

The reversing valve is provided with a stem 314, the end of which is seated in an adjustable cup member 316, see Fig. 28, of a thrust rod 318 that is passed loosely through an opening in the rear wall of the table structure and bears in a boss 320 of an actuating arm 322 fixed on a stud 324 journalled in a block 326 fixed by suitable bolts 328 to the rear side edge part of the table structure. Said block confronts a cam carrying block 330 fixed vertically to the column of the machine.

Said cam carrying block has fixed vertically adjustably thereto by bolts 332 a lower stop block 334 having an inclined cam face 336 leading to a recess 338 in its upper face. The position of said stop block defines the fully retracted position of the table.

The cam block 330 also has vertically adjustably secured thereto by bolts 340 a slow speed or feed cam plate 342 which is effective in setting the reversing valve for a slow or feed-rate of advance of the table. The cam block 330 also carries a second cam plate 344 also vertically adjustably secured thereto, which cam plate effects the reversing of the table.

The lever 322 is provided with a cam roll 346 which cooperates with the aforesaid cams. The lever is biased for pivotal movement in a clockwise direction or away from engagement with the cam block 330 and the cams 342, 344 by a compression spring 348 which at its lower end exerts pressure on a boss 350 of the lever and at its upper end exerts pressure on a stud 352 of the cam block 326. In Fig. 28, the lever 322 is illustrated with the roll in engagement with the cam face 336 of the lower block 334. In this position the reversing valve is in neutral position and the table is held stationary.

To start a cycle of the machine, fluid pressure is applied against the left hand end of the reversing valve, or against the piston 296 thereof, to exert a thrust on the valve stem and to move the lever 322 in a counterclockwise direction

against the spring 348 until the roll is in engagement with the confronting flat face of the cam block 330. This oil pressure is maintained to hold the roll against the cam faces until the valve is moved to the right by the reversing cam at the intended end of stroke of the table or until the oil pressure is released under emergency control to effect retraction of the table. This movement of the reversing valve controls ports to effect the upward movement or advance of the table in a manner presently to be explained. Thus the cam roller 346 is caused to pass over the flat face of the cam block 330 under the slow feed cam 342. This rate of movement is relatively rapid and effects the rapid advance or traverse of the table up to close to the point of engagement between the work and the drill. The feed cam 342 is so positioned that before the drill and the work engage the roll 346 is engaged and moved to the left by the cam 342, thereby changing the setting of the reversing valve to a slow rate of advance of the table, as will presently appear. This slow rate of advance is maintained until the roll comes in contact with the reversing cam 344 whereupon the roll carrying lever 322 is moved to the left and the reversing valve is set to effect rapid retraction of the table. At this time there is no endwise pressure on the reversing valve so that the spring 348 is effective in maintaining the valve set in the table retraction position.

For cycles A, B and C, that is to say, all cycles except the purely hand operated cycle, the start of operation of the cycle is effected by the depression of a foot pedal 354 located on the base of the machine, see Figs. 1 and 31. The foot pedal controls a piston valve 356 located in a valve cylinder 358 having a pair of ports 360, 362 controlled by the pistons 364, 366 of the piston valve, the pistons being located on opposite sides of the ports so that the ports are in communication when the pedal is not depressed. The port 362 is connected to drain by a duct 368. The end of the valve cylinder constantly receives pressure oil from a duct 370 leading to the ports 174 of the main control valve, which ports are constantly in communication with the pressure oil line 72. Thus the duct 370 is under constant oil pressure, which pressure serves to maintain the piston valve in the normal unoperated position illustrated in Fig. 31. Depression of the foot pedal and consequent movement of the piston valve to the left causes the drain port 362 to be closed by the piston 366 and allows pressure oil to flow around the piston 364 from the duct 370 into the duct 360 and through the connecting duct 372 to the cycle selector valve.

The application of pressure oil into the duct 372 under control of the foot pedal effects the application of pressure oil into the endmost chamber 374 of the reversing valve cylinder through the intermediary of the cycle selector valve and the switching piston valves, now to be described.

There are five switching valves, see Figs. 16, 17, 18 and 31, indicated by the Roman numerals I, II, III, IV and V, the pistons of valves I, II, III and V being identical in construction, and valve IV being different. Said valves are located in cylinder bores 376, 378, 380, 382, 384, respectively, of a valve block 386 bolted against the face of the reversing valve block 306 by the aforesaid screws 308. The valve cylinders at their upper ends are closed by the caps 388, 390, 392, 394, 396, respectively. The valves are maintained, when not under endwise oil pressure acting on the tops of the valves, in an upper position by compression springs 398, 400, 402, 404, 406, bearing against the lower ends of the valve and against lower end caps which have inwardly projecting studs 408 to limit the operated lower position of the valves.

The valve I has spaced pistons 410, 412 controlling ports 414, 416 so that when the valve is not depressed there is communication between the ports. The lower piston 412 also controls a third port 418 and normally closes the port, but when the piston is depressed allows communication between the port 416 and the port 418 at which time the port 414 is closed by the upper piston 410. The bottom end part of the valve cylinder is connected freely to drain by a duct 420.

The valve II has upper and lower spaced pistons 422, 424 normally positioned to admit communication between the ports 426, 428. The piston 424 normally closes a third port 430 which is connected freely to drain by a duct 432. The valve in its lower or operated position closes the port 426 and establishes communication between the ports 428 and 430. The bottom of the cylinder is connected to drain through a restricted orifice 434 so that the valve II moves to operated position slower than the valve I which it controls and thereby permits the operation of valve I before the valve II fully operates. The valve II through port 428 controls the admission of pressure oil through a duct 436 to the top of the cylinder of valve I so that the valve I is moved down into an operated position by the application of oil pressure through the duct 436. The operation of valve I effects the movement of the reversing valve into advance position, as will presently appear.

The upper port 426 of valve II is connected to a duct 438 which receives pressure oil through the selector valve as will presently appear. Said duct is also connected with a duct 440 which admits oil under pressure to the top of the cylinder of valve II. Thus when oil under pressure flows into duct 438 valve II is caused to be operated and at the same time through ducts 426 and 428 admit pressure oil to the top of the cylinder of valve I, causing said valve to operate.

The port 416 of valve I is connected by a duct 442 to the end chamber 374 of the reversing valve. The lowermost port 418 of valve I is connected by a duct 444 with the second port 446 of the valve cylinder of valve V. Said valve V has upper and lower pistons 448 and 450 which, in the normal unoperated position of the valve, permit communication between the port 446 and the upper port 452. The upper port is in communication with a high pressure duct 454 connected with the aforesaid high pressure duct 370. The valve V is not operated during the operation of valve I and hence the supply of pressure oil for displacing the reversing valve into starting position is taken through valve IV. Valve V is caused to be operated or moved downwardly by the admission of pressure fluid to the upper end of the valve cylinder through a duct 456 which communicates with the port 414 of valve I and also with the right hand end port 458 of the reversing valve. Said port 458 is controlled by the piston 302 of the piston valve and, in the neutral position of the valve, illustrated in Fig. 31, the port 458 is connected to a drain port 460 of the reversing valve. When the valve piston 302 is in the fast advance, the drain port is sealed and the port 456 is then in communication with the adjacent port 462 which is con-

nected through a duct 464 with the duct 292 that receives oil under pressure to set the main control valve or retraction. Hence at this time valve V is caused to be operated. The lower piston 450 of valve V normally seals a lowermost valve port 466 which is connected through a duct 468 with drain. The bottom end of the valve cylinder is also connected to drain through a restricted orifice 470 so that the action is similar to the orifice 434 of valve II.

Valve IV has upper, intermediate and lower spaced pistons 472, 474, 476, respectively. The valve cylinder has ports 478 and 480 disposed between the upper and intermediate valve pistons and normally in communication. The port 478 is connected to the high pressure duct 454 while the port 480 is connected by a duct 482 with a section of the selector valve. The valve IV also has ports 484 and 486 disposed between the intermediate and lower pistons and normally in communication. The upper port 484 is connected to drain through the duct 468 and the lower port 486 is connected by a duct 488 to a section of the selector valve. The bottom end of the valve cylinder is connected freely to drain by a duct 490. The lowermost piston 476 controls a port 492 and normally seals the port. When, however, the valve is depressed by the application of pressure to the top thereof through a duct 494 leading to a section of the selector valve, said port 492 is placed in communication with the port 486 and receives pressure oil which is transmitted through the duct 292 to the lower valve holding and setting plungers 254, 256.

Valve III has upper and lower pistons 494 and 496 normally admitting communication between the upper and lower ports 498 and 500, but when operated by the application of pressure through the duct 502 closes off communication between these ports and establishes communication between the pressure duct 502 and the port 498. The port 498 is connected through a duct 504 with the duct 146 that admits pressure to the end of the speed setting piston 88 to disable this piston. The port 496 is connected through a duct 506 with a port 508 of the reversing valve.

The reversing valve, in addition to the ports above described, has ports 510 and 512 disposed in communication between the pistons 296, 298 of the reversing valve in the neutral position of the valve. Port 510 opens to a duct 514 which is connected to selector valve sections, as will presently be described, and the port 512 communicates with the duct 299 that is connected to the upper valve holding and valve setting plungers 250, 252. The reversing valve also has a port 516 which is connected to a duct 518 leading to drain. The port is disposed between the pistons 298, 300 of the reversing valve in the neutral position of the valve and is in communication with the port 512 and consequently drains the duct 299 in the fast advance position of the reversing valve and is in communication with the port 508 and consequently drains the duct 506 in the feed position of the reversing valve. The reversing valve also has the ports 520 and 522 disposed between the ports 508 and 462 and located between the valve pistons 300, 302 and in communication with each other and the port 462, in the neutral position of the valve. The ports 520, 522 are connected with a duct 524 which is also connected with the port 510 and leads to an orifice 526 sometimes functioning as a drain orifice and controlled by the spring opened check valve 528 opening into the end chamber 374. The valve closes against the spring pressure when said chamber is under high pressure.

The selection of the switching valves is under control of a cycle selecting valve located in a valve block 530 bolted to the outer face of the switching valve block 386 by the aforesaid bolts or screws 308. The cycle selector valve comprises a drum 532 rotatable in the cylinder bore 534 of the valve block 530. The valve has a reduced axially projecting stud shaft 536 that projects outwardly of the valve block and has fixed thereto an actuating knob 538 provided with a pointer 540 that is rotatable in front of an arcuate series of indicia A, B, C, D, the positions of which correspond to the setting of the valve to condition the mechanism for operation in accordance with the respective cycles A, B, C, D.

The valve drum 532 is provided with three axially spaced series of passages located in the planes X, Y, Z, Fig. 23, adapted to register with corresponding passages in the valve block, the passages being spaced ⅛ of a revolution or 45° apart where they occur. The drum is also provided with a series of notches 542 into which a holding ball 544, see Fig. 20, is adapted to be pressed by the spring 546 to hold the valve releasably in set position. One or more of the entrances of the passages of the first series X also function as the equivalent of the notch 542.

The valve drum 532 nearest the stud 536, or in plane X, has two ports 548 and 550 connected by axially directed internal passages 552 and 554, respectively, with correspondingly positioned ports 556, 558 located in the middle or Y series of ports, as illustrated in Figs. 24, 25 and 27*a*. There is also a port 560 in the first row of ports, located 90° towards the left, Fig. 24, from the port 548 and connected by a diagonal internal passage 562 and opening into a port 564 in the second row Y of ports.

The second port row Y also has a port 566 diametrically opposite the port 556 and connected thereto by a diametrical internal passage 568. The second port row also has three peripherally consecutive ports 570, 572 and 574 connected by a passage 576. The second port row Y also has another port 578 located between the ports 558 and 564 and connected by an axially directed passage 580 with a similarly positioned port 582 in the third port row Z.

The third port row Z has four peripherally consecutive ports 584, 586, 588 and 590 connected together by a common duct 592 and located in axial line with the ports 566 and 570 and so forth, of the second port row.

The X series of ports are drain ports. The remaining series Y and Z handle pressure oil.

The valve block 530 is provided with three axially spaced sets of ports adapted to register with the three series of ports in the rotary selector valve. The block in the plane registering with the port row X of the selector value, as illustrated in Fig. 20, has a port 594 located 45° to the left of the vertical and communicating with a duct 596 that communicates with the duct 514. There is also a port 598 disposed 45° to the right from the vertical that communicates with a duct 600 that goes to drain.

The valve block 530, in the position registering with the second port row Y, as illustrated in Fig. 21, has a port 602 disposed on the left horizontal and a second port 604 between said port and the vertical. Said two ports are in communication with the aforesaid duct 372 that com-

municates with the port 350 of the foot pedal piston valve. There is also a port 606 disposed in the upper vertical that communicates with the duct 438 that admits pressure into the top of switching valve II for operating it. 45° displaced from the port 606 is another port 608 that communicates with the duct 502 for admitting pressure to the top of switching valve III. There is also another port 610 that communicates with the aforesaid duct 438. There is a last port 612, 45° displaced beneath the first port 602, and said port 612 communicates with the duct 494 that admits pressure fluid to the top of switching valve IV for operating it.

The valve block 530, in the position corresponding to the Z row of rotary valve ports, also has a series of ports for registering with said row of rotary valve ports. These ports comprise a port 614 displaced 45° to the left from the vertical, and communicating with a duct 616 that opens to the duct 514 that leads to the port 512 of the reversing valve. A port 618, 90° displaced to the right from the port 614, communicates with a duct 492 that opens to the second port 480 of switching valve IV. 45° displaced from the port 618, in a clockwise direction, is a port 620 communicating with a duct 488 opening to the fourth port 486 of switching valve IV. 90° displaced from the port 614, in a counter-clockwise direction, is a port 622 communicating with a duct 624 that opens to the high pressure duct 454.

Before describing in detail the operation of the various parts of the control system, the general principles of operation of the system will be described.

For the performance of the automatic cycle in its various modifications the direction of movement of the table, and the holding stationary of the table are obtained through the main control valve 196. That is to say, the valve is shifted into one or the other of its two operated positions for fast advance or retraction or is positioned in its neutral or midposition to hold the table stationary or for the feeding of the table at the cutting rate of movement. Such movement of the table is controlled by the speed-setting or throttle valve 88, which valve is held closed except when the reversing valve is in feed position. That is to say, at the start of fast advance, the actuating cylinder receives operating oil through the main control valve. When the cams move the reversing valve to slow feed position, the main valve is moved to neutral position and the throttle valve is placed in operation and supplies the oil for advancing the table. When the reversing valve is placed in retraction position, the main valve is again operated but in the opposite direction to supply the oil for retracting the table.

The desired movements of the main valve are obtained by shifting the reversing valve from one position to the other by the cams and by operation of the foot pedal.

The reversing valve is constantly biased by its spring 348 for movement into retraction position. In neutral position, the valve is held against movement into retracted position by the lower or neutral cam block 334. The valve is moved from neutral to fast advance position against the bias of its spring by the application of oil pressure against the end of the valve, acting in the end chamber 374. This pressure is first applied to start the upward movement of the table and is maintained during the fast advance and feed movements of the table to hold the valve under control of the cams. This pressure is removed by movement of the reversing valve when the valve is moved into retraction position at the end of the feed stroke.

The initial application of pressure to shift the reversing valve is initiated by the depressing of the foot pedal. Shifting of the valve from retraction to fast advance position takes control of the pressure away from the pedal and places it under control of the valve itself except that the pressure can be removed by operation of the pedal in any part of the fast advance and feed strokes to effect retraction of the table as may be required upon drill breakage and the like.

Switching valve I effects the initial application of pressure to the reversing valve to move it from neutral to fast advance position. The operation of valve I is effected through valve II which is a control valve for valve I. Valves I and II receive pressure oil simultaneously from the pedal and hence start to operate together. Valve I operates quickly while valve II operates slowly. Thus valve I operates to admit pressure oil against the end of the reversing valve and to shift the valve from neutral before valve II has completed its operating movement. The reversing valve, upon being shifted continues the oil pressure on the end of the valve and valve II when compeltely operated releases the operating pressure on valve I so that it returns to unoperated position. A primary purpose of valve II is to permit the momentary operation of valve I.

Valve III controls the operation of the throttle valve. Said valve III is primarily under control of the reversing valve and is energized through the reversing valve when the latter is in fast advance position to disable the throttle valve and is de-energized when the reversing valve is in feed position so that the throttle valve can control the feed rate of the table.

Valves IV and V are utilized to effect emergency retraction of the table when the system is operating in accordance with one of the several cycles of operation, particularly cycle C.

The operation of the system will now be described, and Fig. 31 illustrates the setting of the selector valve for the performance of cycle A.

It will be remembered that in cycle A the foot pedal 354 is depressed to start the rapid advance of the table up to the region of engagement between the drill and the work and that the table stops when the drill is close to the work so that the operator can assure himself that everything is proper to continue the drilling operation. The releasing of the pedal from its depressed position effects the re-advance of the table, but at the slow or feed-rate. When the table has reached the desired limit of upward movement and the hole has been drilled to the required depth, the table automatically returns and stops in its lowermost or retracted position. Depression of the pedal at any part of the advancing movement of the table effects the retraction of the table to its fully retracted position and the stopping of the table in the retracted position.

In the fully retracted position, the reversing valve 294 is in neutral position, as illustrated in Fig. 31. The depression of the foot pedal 394 admits fluid from the high pressure duct 370 into the duct 372 where the pressure passes through certain of the Y series of ports in the selector valve and into ducts 438 and 502, causing the instant operation of switching valve III, the delayed operation of switching valve II, by reason

of the restricted exhaust port 434 of said valve, and the instant operation of switching valve I.

The operation of valve III admits pressure oil from the duct 502 to the duct 504 for disabling the speed setting or throttle valve 88 by holding the valve closed so that no oil can get to the actuating cylinder through the duct 132 from this valve so that the oil for operating the cylinder must flow through the main valve 196. This condition is maintained so long as the pedal 354 is depressed.

The operation of switching valve I places the ports 416 and 418 thereof in communication so that pressure oil from the duct 454 can flow through valve V, which is unoperated, and duct 444 into duct 442 and thence into the end chamber 374 of the reversing valve. The building up of pressure on the end of the reversing valve moves the valve to the right and hence moves the cam roll 346 against the fast advance face of the cam block 338, as illustrated in Fig. 31*a*, thereby conditioning the system for fast advance or upward movement of the table.

For fast advance of the table, the main control valve 196 must be in its upper position with the high pressure port 174 in communication with the port 172 leading to the top of the actuating cylinder and with the port 176 communicating with the lower end of the cylinder opening to drain. Thus the lower valve setting plungers 254 and 256 must be under pressure and the upper plungers 250 and 252 free from pressure and hence the duct 292 must be under pressure and the duct 290 must be free from pressure.

In the neutral position of the reversing valve, however, both ducts 290, 292 are under pressure to hold the control valve 196 in neutral position. The duct 290 communicates with the port 212 of the reversing valve which, in turn, communicates with the port 510 that receives pressure oil from the duct 514. The duct 292 communicates through duct 464 with the port 462 of the reversing valve. This port is in communication with a port 522 that communicates through the duct 524 with the duct 514. Hence both ducts 290, 292 are under pressure. The duct 514 receives its pressure through the communicating ducts 616 and 482 of the Z row of ports in the selector valve. The duct 482 receives pressure through the communicating ports 478 and 480 of valve IV, and the pressure duct 454.

When the foot pedal is depressed and the position of the reversing valve changes to fast advance, the reversing valve shifts in position to connect the duct 290 with the drain port 516. The duct 462, controlling the pressure to the lower plungers 254, 256, still remains in communication with high pressure through the port 522 of the reversing valve, the duct 524, the port 510, the oil flowing around the piston section 292 that at this time confronts the port and communicating with the aforesaid high pressure duct 514. Hence the pressure on the plungers 254, 256 forces the main valve 196 upward to effect fast advance of the table.

The switching valves I, II and III are held down since the foot pedal remains depressed and the table advances at its fast rate of speed until the roller 346 engages and rides upon the feed cam 342 and hence is displaced to the left and consequently displaces the reversing valve to the left into some position as illustrated in Fib. 31*b*. In this position, the table movement is intended to be arrested and advance of the table is not intended to be resumed until the foot pedal 354 is raised. Thus the shifting of the reversing valve into feed position effects the return of the main control valve 196 to its neutral position by applying pressure to the upper valve setting plungers 250, 252.

In the feed position of the reversing valve the intermediate piston section 292 interrupts communication between the port 512 and the drain port 516 and places the port 512 in communication with the pressure port 510. Thus pressure oil flows into the duct 290 and against the plungers 250, 252 and balances the action of the lower plungers 254 and 256 so that the valve springs associated with the main valve 196 are effective in moving the valve into the mid or neutral position. Thus the table is stopped for movement at the beginning of the feed stroke.

The starting of the feed stroke is accomplished by removing foot pressure on the pedal and allowing the oil pressure on the end of the pedal operated piston 364 to restore the piston to the neutral position illustrated in Fig. 21.

Upon release and consequent restoration of the piston, the control valve 196 is maintained in the neutral position in the manner just described and feed control of the table movement is obtained through the speed regulating or throttle valve 88. This is effected in the following manner. When the pedal is released and the pedal piston valve 364 returns to neutral, communication between the high pressure duct 370 and the duct 372 is interrupted and the duct 372 is connected to drain duct 368. Thus pressure is removed from the switching valves III, II and I.

It might be stated that switching valve I was only momentarily depressed by the initial depression of the foot pedal and that valve I, after the initial operation, returned to its unoperated position. That is to say, the depression of foot pedal put operating pressure on the ends of both valves I and II. Valve I went down instantly, however, while valve II went down at a slower rate due to the restricted throttle opening 434. This slower rate of operation was sufficient to effect the operation of valve I and the shifting of the reversing valve from neutral to fast advance position. When, however, valve II was in fully operated position it connected the top of valve I with drain through the ports 428 and 430 and hence valve I returned to normal unoperated position by means of its spring.

The shifting of the operating valve from neutral to fast advance position, however, places the reversing valve port 458 in communication with the port 522, which port receives pressure oil through the duct 514 and through the section Z of the selector valve and unoperated switching valve IV from the high pressure duct 370. Thus the duct 456 connected with the port 458 is under pressure and oil flows through the connected ports 414 and 416 of valve I in its operated position and thence to the end chamber 374 of the reversing valve maintaining the valve against the cam faces. Pressure in the duct 456 also operates on the end of the switching valve V and operates it, cutting off communication between the ports 452, 446, but for cycle A performing no other essential function. Thus the switching valve I is merely operated momentarily to initiate the setting of the reversing valve and the reversing valve maintains itself under oil pressure to maintain its cam roller in engagement with the cams.

The retraction of the foot pedal 354, as above

described, effects the return of switching valve III to an unoperated position and hence takes pressure off the throttle valve 88 so that the duct 146 communicating with the throttle valve drains through the ports 498 and 500, which are now in communication, and through the duct 506 and the communicating ports 508, 516 to drain. The throttle valve 88 can thus open under influence of its spring 102 to the extent determined by the setting of the valve setting arm 110 and allows oil to flow through the high pressure duct 72 and the throttle valve ducts 122, 124 and through the governing valve 90 into the top of the cylinder through the duct 132. The table thus advances at a feeding rate of speed as determined by the setting of the throttle valve and at a constant rate regardless of variable thrust between the drill and the work under control of the governing valve 90.

At the end of the slow or feed traverse of the table, the cam roller 346 engages the reversing cam 344 and moves the reversing valve to the extreme left hand or retraction position illustrated in Fig. 31c.

To effect retraction, the throttle valve 88 is again disabled or closed so that control of the operating fluid to and from the actuating cylinder is under control of the main valve 196 and said main valve is moved into a depressed position to allow pressure fluid to flow through the port 176 thereof and the duct 136 into the bottom end of the cylinder and exhaust oil to flow from the top end of the cylinder through the duct 132 and the valve port 176 to the drain 74.

To effect depression of the valve 196, the lower valve setting plungers 254, 256 are freed from oil pressure so that they can be depressed and the upper valve setting plungers 250, 252 are put under oil pressure so that they are moved downward to depress the valve 196. Thus the duct 292 is free from pressure and the duct 290 is placed under pressure. At this time also there is no need for maintaining oil pressure in the end chamber 374 and against the end of the reversing valve and this chamber is freed from pressure by the positioning of the piston section 302 between the port 458 and the pressure port 522 and hence connecting the port 458 and the chamber 374 to drain through the port 460 and the switching valve I. The lower valve setting plungers 254, 256 are freed from pressure and connected with drain by the said piston section 302 which establishes communication between the port 362 in communication with the duct 292 and the drain port 460. The upper plungers 250, 252 are placed under oil pressure through the duct 290 which communicates with the port 512 of the reversing valve and said port is in communication with the pressure port 510 in the retraction position of the reversing valve, as illustrated in Fig. 31c.

When the table arrives in fully retracted position, the roller 346 engages the cam face 336 of the lower cam block 334 and is caused to set the valve into the neutral position illustrated in Fig. 31, thereby stopping the mechanism in fully retracted position and returning the control valve 196 in neutral position by placing both the upper and lower valve setting plungers 250, 252 and 254, 256 under pressure.

Emergency retraction of the table from any advanced position thereof either in a fast advance position or a feed position is accomplished by a depression of the foot pedal 384 and through the foot pedal the movement of the reversing valve into a retraction position, as illustrated in Fig. 31c. It will be remembered that in both fast advance and feed positions of the reversing valve, the reversing valve is under endwise pressure from the pressure of oil in the end chamber 374 and is held by this pressure against the counter-pressure of the spring 348. Thus the emergency depression of the foot pedal is utilized to relieve the chamber 374 from oil pressure so that the spring 348 can operate to move the reversing valve into retraction position, as illustrated in Fig. 31c.

The depression of the foot pedal operates the switching valves III, II and I as before. The valve III disables the feed control or throttle valve 88 if this valve is in use as it will be in the feed position of the reversing valve. The valve II permits the operation of the valve I. The valve I, through its ports 414, 416, which in fast advance and feed positions of the emergency valve are under oil pressure from the duct 456, controls the application of oil pressure to the duct 442 and hence to the end chamber 374. The closing of the valve cuts off communication between these ports and places the port 416 communicating with the chamber 374 in communication with the lower port 418. This port is in communication with the port 446 of valve V. Valve V is in a depressed or operated position since the duct 456 is under oil pressure and hence port 446 is in communication with port 450 which is connected to the drain duct 468. Thus the operation of the valve I connects the end chamber 374 of the reversing valve with the drain. Hence the holding pressure is removed from the emergency valve and the spring 348 is permitted to operate to move the valve into the retraction position and effect the return of the table to fully retracted and stop position.

Cycle B is essentially the same as cycle A, except that when the table is started to advance it does not come to rest with the drill and the work about in engagement, but continues its movement although at the slower or feed-rate to bring the work into engagement until the required depth of the hole is drilled, whereupon the table is retracted rapidly to its fully retracted position.

The cycle is initiated by the depression of the foot pedal as before. Thus in response to the depression of the foot pedal the table advances at a rapid rate up to the drill and then at a slower rate with the drill and work in engagement and then is retracted rapidly to separate the drill and the work and stops in a retracted position. A subsequent depression of the foot pedal causes the return or retraction of the carriage from any advanced position thereof either in a fast advance position or a feed position.

Selection of cycle B is accomplished by rotating the selector valve 532 in a counter-clockwise direction 45° from the positions illustrated in Fig. 31 to the position illustrated in Fig. 32. In this position, the high pressure duct 514 leading to the high pressure port 510 of the reversing valve receives high pressure oil through the duct 614 and the valve ports in the Z line of passages directly from the high pressure duct 370 instead of the pressure passing through valve IV as in cycle A. The pedal operated valve, however, still maintains control of valve II through the ports 602 and 606 of the Y section of the selector valve block, which ports are respectively connected to the duct 372 leading to the pedal valve and the duct 438 leading to valve II. Valve III is thus cut out of operation as is also valve IV. Hence the

only valves functioning are valves I, II and V. The cycle is started by the depression of the foot pedal as before. This causes valve II to be operated and also valve I. The operation of valve I places the chamber 374 under oil pressure and moves the reversing valve from a neutral position to a fast advance position as in Fig. 31a. It will be remembered that, in cycle A, table movement was arrested at the end of the fast approach stroke and then resumed for the feed stroke upon release of the pedal. This was done by holding valve III depressed so that when the reversing valve moved to feed position and thereby moved the control valve 196 into neutral position, the throttle valve 88 was also closed by pressure of oil on the end of it received through the valve III and that when the foot pedal was released and the valve III returned to neutral position the holding pressure on the throttle valve was released so that oil could flow into the cylinder through the throttle valve to cause the cylinder and table to resume its advance at the feed-rate.

In cycle B, however, valve III is out of use and is maintained in an elevated position. Hence during the fast advance stroke the throttle valve 88 is held closed by endwise pressure of oil thereon flowing through the duct 146 and through the communicating ports 498 and 500 of the valve III and through the duct 506 and the communicating ports 508 and 520 of the reversing valve from the pressure duct 524. When the reversing valve moves from fast advance to feed position, the ports 508 and 520 are isolated from each other by the piston section 300 and the port 508 is placed in communication with the drain port 516, thereby relieving the throttle valve from holding pressure and allowing the throttle valve under action of its spring to assume a position determined by the setting of the speed arm 110. The rest of the cycle is accomplished, as has been above described in connection with cycle A.

Emergency return of the table from any advanced position thereof is accomplished by a second depression of the foot pedal. This causes the second operation of valves II and I. The operation of valve I drains pressure oil from the end chamber 374 of the reversing valve and allows the spring 348 to move the valve into retraction position, as has been explained in connection with cycle A.

Cycle C is a continuous repetition of the automatic cycle effected by depressing and holding down the pedal. Emergency return from any advanced position of the table is effected by the release, depression and release of the pedal.

The system is conditioned for cycle C operation by the rotation of the cycle selector valve a second 45° from the cycle B position or 90° from the cycle A position illustrated in Fig. 31 or into the position illustrated in Fig. 33. In this position, the high pressure duct 514 leading to the high pressure port 510 of the reversing valve receives pressure oil as before through the ducts 616 and 614 and the passages of the Z line of ports in the rotary selector valve. That is to say, the duct 616 is in communication with the port 590 of the selector valve while the duct 614 is in communication with the duct 586 of the selector valve. The duct 482, associated with the Z line of ports, is isolated. The duct 488 is connected through the port 582 and the internal passage 530 in the rotary valve with the port 578 in the Y line of ports, and through this port with the duct 438 associated with valve II. The pressure duct 372 from the pedal valve is connected through the passage 576 of the rotary valve with the duct 494 which conducts pressure fluid into the top of the switch valve IV for operating it. With this setting of the cycle selector valve, valve III is out of operation as it was in cycle B.

In starting the cycle, the pedal is depressed as before and is held depressed. This admits pressure oil through the duct 372 into the duct 494 to effect the depression of valve IV. Valve IV has a port 492 which is in communication with the ducts 282 and 484 and with the reversing valve port 462, that in the neutral position of the reversing valve, is under oil pressure. Valve IV also has a port 486 that is in communication through duct 488 and the internal passage 580 of the reversing valve with the pressure duct 438 associated with valve II. Thus depression of valve IV under pedal pressure establishes pressure communication between the reversing valve and valve II and effects the depression of valve II. Valve I receives pressure oil from valve II and hence is also depressed and at a more rapid rate as has been explained above. Valve I has a port 418 connected with the port 446 of valve V which is under oil pressure from a duct 494, as has been explained above. Thus depression of valve I places ports 416 and 418 in communication and allows high pressure oil from the duct 454 to flow into the end chamber 374 of the reversing valve, moving this valve from neutral into fast advance position where the rest of the cycle is carried out as has been explained in connection with cycles A and B.

Automatic repetition of the cycle is accomplished by maintaining the pedal depressed because when the reversing valve is placed in neutral position at the end of the cycle conditions are restored to effect the repeated operation of valve I, as has been explained for the start of the cycle, and thus the cycle is repeated indefinitely as long as the pedal is held depressed.

Emergency retraction of the table from any advanced position thereof is obtained by the release, depression and release of the pedal. The consequence of this operation of the pedal is to relieve the end chamber 374 of the reversing valve from pressure. The release of the pedal in some advanced position of the table restores valve IV to an unoperated position. In this position valves I and II are free from oil pressure since the port 486 is now isolated from the pressure port 492 that receives pressure oil from the port 462 of the reversing valve in fast advance and feed positions of the valve. As a consequence, valve II returns to its unoperated position. The end chamber 374, however, is still under oil pressure, the pressure being transmitted through the communicating ports 414 and 416 of valve I from the duct 456 and the port 458 of the reversing valve. This is true in the fast advance position but in the feed position of the valve this port is connected to drain so that endwise pressure on the reversing valve is relieved and the reversing valve is returned to retraction position by its spring. Thus, when the table happens to be in some feed position, the release of the pedal accomplishes retraction. If the table is in a fast approach position, however, the pedal valve has to be again depressed. Depression of the pedal valve again operates valve IV which admits pressure oil to valves I and II as before and causes their operation. The operation of valve I connects the end chamber 374 through port 416 of valve I with port 418 of this valve. Port 418, however, is connected by duct

444 with port 446 of valve V. This valve is in an operated position since it is under endwise pressure through the duct 456 from the port 458 of the reversing valve, which port in the fast advance position of the valve is in communication with the pressure port 522. Thus port 446 of valve V is in communication with port 466 of the valve, which port is connected to the drain duct 468. Hence the depression of valve I in response to the depression of valve IV relieves the end chamber 374 of the reversing valve from pressure and, consequently, the reversing valve moves to retracted position to effect the retraction of the table.

In cycle D, the system is set for entire manual control by the operating handle 234 and the foot pedal is not used. The reversing valve remains in retraction position except as it may be moved into neutral position by its control cam 534 when the table is moved manually to the far end of its stroke but the reversing valve does not either in neutral or in retraction position effect any control over any parts of the system.

In setting the cycle selector valve to position for cycle D, the valve is rotated 45° in a counterclockwise position, or 135° from the cycle A position and into the position illustrated in Fig. 34. In this position the only control that is effected is the control of switching valve III which is held down and caused to apply pressure onto the end of the throttle valve 88 to hold the valve closed. Valve III and throttle valve 88 are held in such positions constantly during the time that the cycle selector valve is in cycle D position.

In the setting of the selector valve for cycle D position, pressure oil passes from the pressure duct 370 and the duct 454 through the communicating ports 478, 480 of unoperated valve IV through the duct 482 to section Z of the selector valve and through the internal passage 580 of said valve, which passage now registers with the duct 482, and to section Y of the valve where the duct now registers with the duct 592 leading to the top of selector valve III. Pressure is constantly applied to the valve and the valve is held down in an operated position by the pressure and connects the pressure duct 592 with the duct 594 which communicates the pressure with the top of the throttle valve 88, thereby holding the throttle valve down and preventing pressure oil from passing from the duct 72 into the actuating cylinder. Thus the actuating cylinder is prevented from receiving oil except as introduced by the manual operation of the main control valve 196; and said main control valve is freed from all controlling pressure so that it can move in response to movements of the operating handle.

In cycle D, for hand operation, the rack 244 of Figs. 1 and 9, is clamped against movement in the standard 246. For the automatic cycles A, B and C, however, the rack is unclamped from the standard and so is free to move with the table.

I claim:

1. In a drilling machine, a drill, a work support, means including a hydraulic motor for effecting movement of one of the aforesaid elements relatively to the other element, a source of actuating fluid, valve mechanism operative into different settings for differently controlling the flow of fluid between said motor and source and the operation of said motor, cam mechanism controlling said valve mechanism and operative to effect predetermined changes in the setting thereof at predetermined positions of said movable element, and manually controlled valve means having different selector settings associated with said valve mechanism and operative in different settings thereof to effect different manners of operation of said motor for the same setting and under control of said valve mechanism.

2. In a drilling machine, a drill, a work support, means including a hydraulic motor for effecting movement of one of the aforesaid elements relatively to the other element, a source of actuating fluid, valve mechanism controlling the flow of fluid between said motor and said source, cam mechanism controlling said valve mechanism and operative to shift said valve mechanism into positions to secure a predetermined length of rapid advance of said moveable element from a predetermined starting position followed by a predetermined length of slower advance and a rapid retraction to the starting position, and manually controlled valve mechanism for modifying the action of said motor under control of said cam controlled valve mechanism and operative to secure the arrest of said movable element at the end of said predetermined length of rapid advance, and manually controlled valve means operative to effect the re-starting of advance of the movable element at slow speed.

3. In a drilling machine, a drill, a work support, means including a hydraulic motor for effecting movement of one of the aforesaid elements relatively to the other element, a source of actuating fluid, valve mechanism controlling the flow of fluid between said motor and said source, cam mechanism controlling said valve mechanism and operative to shift said valve mechanism into positions to secure a predetermined length of rapid advance of said movable element from a predetermined starting position followed by a predetermined length of slower advance and a rapid retraction to the starting position, manually controlled valve mechanism for modifying the action of said motor under control of said cam controlled valve mechanism and operative to secure the arrest of said movable element at the end of said predetermined length of rapid advance, and manually controlled valve means operative to effect the automatic re-advance of said movable element from its start position.

4. In a drilling machine, a drill, a work support, means including a hydraulic motor for effecting movement of one of the aforesaid elements relatively to the other element, a source of actuating fluid, valve mechanism controlling the flow of fluid between said motor and source, cam mechanism controlling said valve mechanism and operative to effect a change in the operation of said motor at predetermined positions of said movable element, and manually controlled valve means associated with said valve mechanism and operative to modify the manner of operation of said motor under control of said valve mechanism, said manually controlled valve means having means operative to secure retraction of said movable element from any advanced position thereof and to effect the arrest of said element in its fully retracted position.

5. In a drilling machine, a drill, a work support, means including a hydraulic motor for effecting movement of one of the aforesaid elements relatively to the other element, a source of actuating fluid, valve mechanism controlling the flow of fluid between said motor and said source, cam mechanism controlling said valve mechanism and operative to shift said valve mechanism into positions to secure a predetermined length of rapid advance of said movable

element from a predetermined starting position followed by a predetermined length of slower advance and a rapid retraction to the starting position, manually controlled valve mechanism for modifying the action of said motor under control of said cam controlled valve mechanism and operative to secure the arrest of said movable element at the end of said predetermined length of rapid advance, and manually controlled valve means operative to effect the restarting of advance of the movable element at slow speed, said manually controlled valve means having means operative to secure retraction of said movable element from any advanced position thereof and to effect the arrest of said element in its fully retracted position.

6. In a drilling machine, a drill, a work support, means including a hydraulic motor for effecting movement of one of the aforesaid elements relatively to the other element, a source of actuating fluid, valve mechanism controlling the flow of fluid between said motor and said source, cam mechanism controlling said valve mechanism and operative to shift said valve mechanism into positions to secure a predetermined length of rapid advance of said movable element from a predetermined starting position followed by a predetermined length of slower advance and a rapid retraction to the starting position, manually controlled valve mechanism for modifying the action of said motor under control of said cam controlled valve mechanism and operative to secure the arrest of said movable element at the end of said predetermined length of rapid advance, and manually controlled valve means operative to effect the automatic readvance of said movable element from its start position, said manually controlled valve means having means operative to secure retraction of said movable element from any advanced position thereof and to effect the arrest of said element in its fully retracted position.

7. In a drilling machine, a drill, a work support, means including a hydraulic motor for effecting movement of one of the aforesaid elements relatively to the other element, a source of actuating fluid, valve mechanism for controlling the flow of fluid between said motor and source, cam mechanism controlling said valve mechanism and operative to effect a normal operating cycle for said movable element comprising a predetermined length of fast advance from a predetermined stop position followed by a continued advance but at a slow rate for a predetermined length and a rapid retraction to the stop position, and manually controlled selector valve mechanism operative to modify said cycle and arranged in one position to secure the stopping of the movable element at the end of the predetermined length of fast advance and operative in another position to permit the performance of the aforesaid cycle and operative in a third position to effect automatically successive repetitions of the cycle, and manually controlled valve means operative to re-start the advance of the movable element from a stationary position at the end of the fast advance range.

8. In a drilling machine, a drill, a work support, means including a hydraulic motor for effecting movement of one of the aforesaid elements relatively to the other element, a source of actuating fluid, valve mechanism for controlling the flow of fluid between said motor and source, cam mechanism controlling said valve mechanism and operative to effect a normal operating cycle for said movable element comprising a predetermined length of fast advance from a predetermined stop position followed by a continued advance but at a slow rate for a predetermined length and a rapid retraction to the stop position, manually controlled selector valve mechanism operative to modify said cycle and arranged in one position to secure the stopping of the movable element at the end of the predetermined length of fast advance and operative in another position to permit the performance of the aforesaid cycle and operative in a third position to effect automatically successive repetitions of the cycle, and manually controlled valve means operative to re-start the advance of the movable element from a stationary position at the end of the fast advance range, said manually controlled valve means also having means to secure retraction of said movable element from any advanced position.

9. In a drilling machine, a drill, a work support, means including a hydraulic motor for effecting movement of one of the aforesaid elements relatively to the other element, a source of actuating fluid, valve mechanism for controlling the flow of fluid between said motor and source, cam mechanism controlling said valve mechanism and having movement relatively thereto to position said valve mechanism to admit fluid to said motor in an amount and in a direction to secure rapid advance of said movable element for a predetermined distance and then to shift the position of said valve mechanism to reduce the rate of advance over a predetermined distance and then further to shift the position of said valve mechanism to effect retraction of said movable element to its starting position, and manually controlled valve means operative for any setting of said valve mechanism to admit fluid to said motor independently of the position of said valve mechanism with respect to said cam mechanism and in a direction to effect rapid retraction of said movable element from any advanced position thereof.

10. In a drilling machine, a drill, a work support, means including a hydraulic motor for effecting movement of one of the aforesaid elements relatively to the other element, a source of actuating fluid, valve mechanism for controlling the flow of fluid between said motor and source, cam mechanism controlling said valve mechanism to effect the advance of said movable element from a stop position at different rates of speed and its retraction to said stop position from a predetermined advanced position, a manually depressible valve member and valve means responsive to the release, depression and release of said depressible valve member for effecting retraction of said movable element from any advanced position thereof.

11. In a drilling machine, a drill, a work support, means including a hydraulic motor for effecting movement of one of the aforesaid elements relatively to the other element, a source of actuating fluid, valve mechanism for controlling the flow of fluid between said motor and source, cam mechanism controlling said valve mechanism to effect the advance of said movable element from a stop position at different rates of speed and its retraction to said stop position from a predetermined advanced position, a manually depressible valve member, and valve means responsive to the depression and release of said depressible valve member for effecting retraction of

said movable element from any advanced position thereof.

12. In a drilling machine, a drill, a work support, means including a hydraulic motor for effecting movement of one of the aforesaid elements relatively to the other element, a source of actuating fluid, valve mechanism for controlling the flow of fluid between said motor and source, cam mechanism responsive to the position of said movable element and operative to control said valve mechanism to effect a predetermined length of fast advance of said movable element from a retracted position, a further predetermined length of advance of said movable element but at a slower speed and a fast retraction of said movable element to said stop position, a manually depressible valve member, and valve means responsive to said depressible valve member responsive to the continued depression of said depressible valve member to effect the advance of said movable element from the stop position, and the stopping of said element at the end of its predetermined length of fast advance and responsive to the release of said depressible valve member to effect the re-starting of advance of said movable element at a slower rate of speed.

13. In a drilling machine, a drill, a work support, means including a hydraulic motor for effecting movement of one of the aforesaid elements relatively to the other element, a source of actuating fluid, valve mechanism for controlling the flow of fluid between said motor and source, cam mechanism responsive to the position of said movable element and operative to control said valve mechanism to effect a predetermined length of fast advance of said movable element from a retracted position, a further predetermined length of advance of said movable element but at a slower speed and a fast retraction of said movable element to said stop position, a manually depressible valve member, and valve means responsive to said depressible valve member responsive to the continued depression of said depressible valve member to effect the repeated advance of said movable element from said stop position.

14. In a drilling machine, a drill, a work support, means including a hydraulic motor for effecting movement of one of the aforesaid elements relatively to the other element, a source of actuating fluid, valve mechanism for controlling the flow of fluid between said motor and source, cam mechanism responsive to the position of said movable element controlling said valve mechanism to effect an operating cycle of said movable element comprising a predetermined length of fast advance of said element, a further predetermined length of slow advance, and a retraction of said movable element to a stop position, a plurality of switching valves arranged when operated to modify the control of said movable element by said valve mechanism, a manually depressible valve member arranged for control of said switching valves, and a manually operable selector valve arranged in one position to establish control of said manually depressible valve over one switching valve and in another position over another switching valve, one switching valve when operated by the continued depression of said depressible valve effecting the advance of said movable element from the stop position to a second stop position at the end of its fast advance traverse and operative upon the release of said depressible valve to effect the further advance of said movable element at slow speed, the other of said switching valves being operative when said depressible valve member is held depressed to effect the automatic repeated advance of said movable element from its stop position.

15. In a drilling machine, a drill, a work support, means including a hydraulic motor for effecting movement of one of the aforesaid elements relatively to the other element, a source of actuating fluid, valve mechanism controlling the flow of fluid between said motor and source including a movable valve member shiftable into different positions for securing fast advance, slow advance, and retraction of said movable element and for holding said element stationary in a fully retracted position, cam means movable relatively to said valve member for shifting said valve member from one to another of said positions, spring means constantly acting on said valve member in a direction to move it away from engagement with said cam means, and hydraulic means including a manually operable valve member for applying pressure to said movable valve member in a direction to force it against the action of said spring into the engagement of said cam means.

16. In a drilling machine, a drill, a work support, means including a hydraulic motor for effecting movement of one of the aforesaid elements relatively to the other element, a source of actuating fluid, valve mechanism controlling the flow of fluid between said motor and source including a movable valve member shiftable into different positions for securing fast advance, slow advance, and retraction of said movable element and for holding said element stationary in a fully retracted position, cam means movable relatively to said valve member for shifting said valve member from one to another of said positions, spring means constantly acting on said valve member in a direction to move it away from engagement with said cam means, and hydraulic means including a manually operable valve member for applying pressure to said movable valve member in a direction to force it against the action of said spring into the engagement of said cam means, said manually operable valve member having means to initiate the application of hydraulic pressure to said movable valve member and said movable valve member having means operable upon its shifting in position to maintain the hydraulic pressure thereupon until said movable valve member is further shifted.

17. In a drilling machine, a drill, a work support, means including a hydraulic motor for effecting movement of one of the aforesaid elements relatively to the other element, a source of actuating fluid, valve mechanism for controlling the flow of fluid between said motor and said source and including a movable valve member shiftable into one position on one side of a neutral position to effect rapid advance of said movable element and shiftable into another position on the same side of said neutral position to effect slow advance of said movable element and shiftable into a position on the other side of said neutral position to secure retraction of said movable element, spring means constantly acting on said movable valve member urging it toward a retraction position, cam means associated with said movable valve member for moving it into its several positions, hydraulic means operative on said movable valve member against the action of said spring to hold it in engage-

ment with said cam means, means including a manually controlled valve member for effecting the operation of said hydraulic means to move said movable valve member from a neutral position into an advanced position in engagement with said cam means and also having means operative at any advanced position of said movable element to relieve the pressure of said hydraulic means and to permit said spring to move said movable valve member into retracted position, and means under control of said movable valve member following its initial movement by said hydraulic means from neutral to an advance position to maintain the pressure of said hydraulic means subject to the release of pressure in response to a second operation of said manually controlled valve member.

18. In a drilling machine, a drill, a work support, means including a hydraulic motor for effecting movement of one of the aforesaid elements relatively to the other element, a source of actuating fluid, valve mechanism for controlling the flow of fluid between said motor and said source and including a shifting valve member, cam means for shifting said valve member, hydraulic means for shifting said valve member to hold it in engagement with said cam means, and means including a manually controlled valve member operative to effect the release of pressure of said hydraulic means on said shiftable valve member and the shifting of said valve member to effect retraction of said movable element from any advanced position thereof.

19. In a drilling machine, a drill, a work support, means including a hydraulic motor for effecting movement of one of the aforesaid elements relatively to the other element, a source of actuating fluid, a valve for controlling the flow of fluid between said motor and source for effecting rapid movement of said movable element, a throttle valve independently of said first valve controlling the flow of fluid between said motor and source for effecting slow movement of said movable element, and cam controlled valve mechanism responsive to positions of said movable element operative to shift control of said movable element between said first valve and said throttle valve.

20. In a drilling machine, a drill, a work support, means including a hydraulic motor for effecting movement of one of the aforesaid elements relatively to the other element, a source of actuating fluid, a valve for controlling the flow of fluid between said motor and source for effecting rapid movement of said movable element, a throttle valve independently controlling the flow of fluid between said motor and source for effecting slow movement of said movable element, and cam controlled valve mechanism responsive to positions of said movable element operative to shift control of said movable element between said first valve and said throttle valve, and manually controlled valve means operative to free said valve mechanism from control of its cam and to establish fluid connections between said motor and source through said first valve.

21. In a drilling machine, a drill, a work support, means including a hydraulic motor for effecting movement of one of the aforesaid elements relatively to the other element, a source of actuating fluid, a valve controlling the flow of fluid between said motor and said source having a normal mid position where fluid flow is interrupted, and a position on one side of said normal position effective in securing movement of said movable element in one direction and having a second position on the opposite side of said normal position operative to secure movement of said movable element in the opposite direction, hydraulic operating means for said valve operative to move said valve from said mid position into said other positions, valve mechanism for operating said hydraulic means, and cam means responsive to the position of said movable element for operating said valve mechanism.

22. In a drilling machine, a drill, a work support, means including a hydraulic motor for effecting movement of one of the aforesaid elements relatively to the other element, a source of actuating fluid, a valve controlling the flow of fluid between said motor and said source having a normal mid position where fluid flow is interrupted, and a position on one side of said normal position effective in securing movement of said movable element in one direction and having a second position on the opposite side of said normal position operative to secure movement of said movable element in the opposite direction, hydraulic operating means for said valve operative to move said valve from said mid position into said other positions, valve mechanism for operating said hydraulic means, cam means responsive to the position of said movable element for operating said valve mechanism, and manually controlled valve means operative independently of the relative position of said valve mechanism with respect to said cam means for effecting a setting of said valve mechanism in a manner other than called for by the relative position of said valve mechanism and cam means.

23. In a drilling machine, a drill, a work support, means including a hydraulic motor for effecting movement of one of the aforesaid elements relatively to the other element, a source of actuating fluid, a valve controlling the flow of fluid between said motor and said source having a normal mid position where fluid flow is interrupted, and a position on one side of said normal position effective in securing movement of said movable element in one direction and having a second position on the opposite side of said normal position operative to secure movement of said movable element in the opposite direction, hydraulic operating means for said valve operative to move said valve from said mid position into said other positions, valve mechanism for operating said hydraulic means, cam means responsive to the position of said movable element for operating said valve mechanism, and manually operative valve means for effecting a shifting of said valve mechanism into a position for securing retraction of said movable element independently of the relative position between said cam means and valve mechanism.

24. In a drilling machine, a drill, a work support, means including a hydraulic motor for effecting movement of one of the aforesaid elements relatively to the other element, a source of actuating fluid, a main control valve controlling the flow of fluid between said motor and source and movable in opposite directions from a mid position for effecting respectively rapid advance and rapid retraction of said movable element, a throttle valve controlling the flow of fluid between said motor and said source independently of said main control valve and movable from a closed position into an open position that is effective to secure the slow advance of said movable element, hydraulic operating means for shifting said main control valve from one

side to the other of its mid position, hydraulic operating means for said throttle valve operative to move it from an open position to a closed position, valve mechanism controlling both hydraulic operating means, and cam means movable relatively to said valve mechanism for operating said valve mechanism in accordance with the position of said movable element.

25. In a drilling machine, a drill, a work support, means including a hydraulic motor for effecting movement of one of the aforesaid elements relatively to the other element, a source of actuating fluid, a main control valve controlling the flow of fluid between said motor and source and movable in opposite directions from a mid position for effecting respectively rapid advance and rapid retraction of said movable element, a throttle valve controlling the flow of fluid between said motor and said source independently of said main control valve and movable from a closed position into an open position that is effective to secure the slow advance of said movable element, hydraulic operating means for shifting said main control valve from one side to the other of its mid position, hydraulic operating means for said throttle valve operative to move it from an open position to a closed position, valve mechanism controlling both hydraulic operating means, cam means movable relatively to said valve mechanism for operating said valve mechanism in accordance with the position of said movable element, and manually controlled valve means operative to effect the setting of said main valve in position to secure retraction of said movable element independently of the cam control of said valve mechanism.

26. In a drilling machine, a drill, a work support, means including a hydraulic motor for effecting movement of one of the aforesaid elements relatively to the other element, a source of actuating fluid, a main control valve controlling the flow of fluid between said motor and said source and movable from a mid position in one direction to secure rapid advance of said movable element and in an opposite direction to secure rapid retraction of said movable element, hydraulic means for moving said valve in opposite directions from mid position, a throttle valve controlling the flow of fluid between said motor and source independently of said main control valve and movable from a closed position to an open position effective to secure slow advace of said movable element, hydraulic means for moving said throttle valve from an open to a closed position, valve mechanism controlling both hydraulic means, cam means movable relatively with respect to said valve mechanism controlling said valve mechanism, said valve mechanism having in one position ports operative to effect energization of the hydraulic operating means for said throttle valve to maintain said valve closed and at the same time to energize the hydraulic operating means for said main control valve to hold said valve in one position to effect rapid advance of said movable element, and said valve mechanism having in another position ports operative to control said hydraulic operating means for said main control valve to position said control valve in mid position and to de-energize said hydraulic operating means for said throttle valve to establish the open condition of said throttle valve to secure slow advance of said movable element, said valve mechanism having in further position ports operative to energize said hydraulic operating means for said throttle valve to close said valve and to energize said hydraulic means for said main control valve to move said valve into a position to secure rapid retraction of said movable element.

27. In a drilling machine, a drill, a work support, means including a hydraulic motor for effecting movement of one of the aforesaid elements relatively to the other element, a source of actuating fluid, a main control valve controlling the flow of fluid between said motor and said source and movable from a mid position in one direction to secure rapid advance of said movable element and in an opposite direction to secure rapid retraction of said movable element, hydraulic means for moving said valve in opposite directions from mid position, a throttle valve controllng the flow of fluid between said motor and source independently of said main control valve and movable from a closed position to an open position effective to secure slow advance of said movable element, hydraulic means for moving said throttle valve from an open to a closed position, valve mechanism controlling both hydraulic means, cam means movable relatively with respect to said valve mechanism controlling said valve mechanism, said valve mechanism having in one position ports operative to effect energization of the hydraulic operating means for said throttle valve to maintain said valve closed and at the same time to energize the hydraulic operating means for said main control valve to hold said valve in one position to effect rapid advance of said movable element, and said valve mechanism having in another position ports operative to control said hydraulic operating means for said main control valve to position said control valve in mid position and to deenergize said hydraulic operating means for said throttle valve to establish the open condition of said throttle valve to secure slow advance of said movable element, said valve mechanism having in further position ports operative to energize said hydraulic operating means for said throttle valve to close said valve and to energize said hydraulic means for said main control valve to move said valve into a position to secure rapid retraction of said movable element, and manually operative valve means controlling the operation of said hydraulic operating means for said control and throttle valves independently of said cam means and having means operative to condition said main and throttle valves to secure retraction of said movable element from any advanced position thereof.

28. In a drilling machine, a drill, a work support, means including a hydraulic motor for effecting movement of one of the aforesaid elements relatively to the other element, a source of actuating fluid, a main control valve controlling the flow of fluid between said motor and source having a valve member movable from a mid position where fluid flow between said motor and source is interrupted in one direction to secure advance of said movable element and movable in an opposite direction from mid position to secure retraction of said element, hydraulically operated plungers acting in opposite directions on said movable valve member to effect movement thereof in opposite directions from the mid position, and valve means for admitting pressure fluid to the action of selected plungers.

29. In a drilling machine, a drill, a work support, means including a hydraulic motor for effecting movement of one of the aforesaid ele-

ments relatively to the other element, a source of actuating fluid, a main control valve controlling the flow of fluid between said motor and source having a valve member movable from a mid position where fluid flow between said motor and source is interrupted in one direction to secure advance of said movable element and movable in an opposite direction from mid position to secure retraction of said element, hydraulically operated plungers acting in opposite directions on said movable valve member to effect movement thereof in opposite directions from the mid position, valve means for admitting pressure fluid to the action of selected plungers, and cam means controlling the action of said valve means in response to predetermined positions of said movable element.

30. In a drilling machine, a drill, a work support, means including a hydraulic motor for effecting movement of one of the aforesaid elements relatively to the other element, a source of actuating fluid, a control valve for controlling the flow of fluid between said motor and source having a movable valve member, means normally retaining said member in a mid position where the fluid flow is interrupted, said valve member being movable in one direction to secure advance of said movable element and movable in an opposite direction to secure retraction of said movable element, a lever connected with said movable valve member for moving it in opposite directions, opposed hydraulically operated plungers acting on said lever in opposite directions to shift it and said valve member in opposite directions, and valve mechanism selectively applying pressure fluid to said plungers.

31. In a drilling machine, a drill, a work support, means including a hydraulic motor for effecting movement of one of the aforesaid elements relatively to the other element, a source of actuating fluid, a control valve for controlling the flow of fluid between said motor and source having a movable valve member, means normally retaining said member in a mid position where the fluid flow is interrupted, said valve member being movable in one direction to secure advance of said movable element and movable in an opposite direction to secure retraction of said movable element, a lever connected with said movable valve member for moving it in opposite directions, opposed hydraulically operated plungers acting on said lever in opposite directions to shift it and said valve member in opposite directions, and valve mechanism selectively applying pressure fluid to said plungers, said valve mechanism including a shiftable member movable in opposite directions from a neutral position and having means for applying pressure to both plungers when said shiftable valve member is in neutral position and for applying pressure to one plunger only when said shiftable valve member is shifted in one direction away from neutral and for applying pressure only to the other plunger when the shiftable valve member is shifted in the opposite direction away from neutral.

32. In a drilling machine, a drill, a work support, means including a hydraulic motor for effecting movement of one of the aforesaid elements relatively to the other element, a source of actuating fluid, main valve mechanism controlling the flow of fluid between said motor and said source and having means operative to secure movements of said movable element in opposite direction and also to hold said movable element stationary, manual means for operating said main valve mechanism to effect movements of said movable element in opposite directions, valve means controlled by the position of said movable element also arranged to control said main valve means, and selector valve mechanism operable at will to place said main valve mechanism under manual control alone and also under control of said valve means.

33. In a drilling machine, a vertically movable work supporting table, a hydraulic piston and cylinder for reciprocating said table, a source of hydraulic fluid for operating said piston and cylinder, a control valve carried by and movable with said table controlling the flow of fluid between said cylinder and source, said control valve having a movable member, means normally holding said member yieldingly in a mid position where fluid flow between said cylinder and source is interrupted, said valve member being movable in one direction to admit fluid flow in a direction to advance said table, and said valve member being movable in the opposite direction from said mid position to admit fluid flow in a direction to retract said table, a lever pivoted to and movable with said table having a connection with said valve member to move it in opposite directions, a manual valve operating member journalled in said lever and having a gear sector thereon, a vertical rack meshing with said gear sector, means for removably securing said rack in fixed position against movement with said table and also for freeing said rack for movement with and by said table, hydraulically operated plungers disposed on opposite sides of said lever for engaging and moving said lever in opposite directions when said rack is free for movement with said table, valve mechanism operative to apply hydraulic pressure selectively to said plungers, cam means movable relatively to said valve mechanism for controlling the operation thereof, and a manually operated selector valve operative to free said valve mechanism from cam control of said plungers and to free said plungers from hydraulic pressure, whereby said lever can be operated manually when said rack is fixed against movement with the table.

34. In a drilling machine, a drill, a work support, a hydraulic motor for effecting movement of one of the aforesaid elements relatively to the other element, a source of actuating fluid, a control valve having means controlling fluid flow between said motor and source to effect advance and retraction movements of said movable element, means including a manually operable lever having a mechanical connection with said valve for operating it, cam controlled valve means responsive to the position of said movable element having operative connections with said control valve for operating it, and manually operated selector valve mechanism operative to condition said control valve for control by said manually operable lever and by said valve means separately.

35. In a drilling machine, a drill, a work support, a hydraulic motor for effecting movement of one of the aforesaid elements relatively to the other element, a source of actuating fluid, a control valve controlling fluid flow between said motor and source, a throttle valve controlling fluid flow between said motor and source independently of said control valve, valve mechanism responsive to the position of said movable element, and means responsive to said valve mechanism for shifting control of said motor be-

tween said control valve and said throttle valve.

36. In a drilling machine, a drill, a work support, a hydraulic motor for effecting movement of one of the aforesaid elements relatively to the other element, a source of actuating fluid, a control valve controlling fluid flow between said motor and source, a throttle valve controlling fluid flow between said motor and source, valve mechanism responsive to the position of said movable element, means responsive to said valve mechanism for shifting control of said motor between said control valve and said throttle valve, a manually operable valve member, and means responsive to the operation of said valve member for effecting control of said control and throttle valves independently of the control thereof by said valve mechanism in accordance with the position of said movable element.

37. In a drilling machine, a drill, a work support, means including a hydraulic motor for effecting movement of one of the aforesaid elements relatively to the other element, a source of actuating fluid, a main control valve controlling the flow of fluid between said motor and said source having one position where the fluid flow is interrupted and the movable element is held stationary and two other positions for securing fast advance and retraction of the movable element, hydraulic means for effecting movement of said valve into any selected one of its three positions, a throttle valve controlling the flow of fluid between said motor and said source operative to effect slow speed advance of said movable element and having a normal open position and a closed position, hydraulic means for moving said throttle valve from said open to said closed position, reversing valve mechanism including a shiftable valve member having different positions operative to secure fast and slow advance and retraction of said movable element, cam means movable relatively to said shiftable valve member and cooperating therewith to move it into its different positions, means constantly biasing said shiftable valve member for movement out of cooperative relation with said cam means, hydraulic means operating on said shiftable valve member to move it against said biasing means into engagement with said cam means, a manually operated valve member controlling movement of said movable element, a switching valve controlling the hydraulic means for said throttle valve, said switching valve being responsive to the operation of said manually operated valve member to effect the closing of said throttle valve and to maintain said throttle valve closed throughout the operated condition of said manually operated valve member, said switching valve being responsive to the release of said manually operated valve member and to control by said reversing valve mechanism in the slow speed position of said shiftable valve member to effect the release of said throttle valve, a starting switching valve responsive to the operation of said manually operated valve member to energize the hydraulic operating means of said reversing valve mechanism to effect movement of said shiftable valve member from neutral to fast advance position, means under control of said shiftable valve member in its fast advance and also slow advance positions to maintain said hydraulic means operative to maintain said shiftable valve member in engagement with said cam means, means responsive to movement of said shiftable valve member from neutral to fast advance position to actuate the hydraulic means for said main control valve to effect the movement of said valve to fast advance position, means responsive to movement of said shiftable valve member from fast advance to slow advance positions to actuate the hydraulic means for said main control valve to move said main control valve to neutral position, means responsive to movement of said shiftable valve member to retraction position to actuate said hydraulic means for said main control valve to move said valve into fast advance position, and means responsive to movement to said shiftable valve member to neutral position to effect movement of said main control valve to neutral position.

38. In a drilling machine as defined in claim 37, said starting switching valve having means responsive to the operation of said manually operated valve member at any advanced position of said movable element to effect the de-energization of the hydraulic means of said shiftable valve member to effect movement of said shiftable valve member into retraction position under urge of said biasing means.

39. In a drilling machine, a drill, a work support, a hydraulic motor for effecting movement of one of the aforesaid elements relatively to said other element, a source of actuating fluid, means including valve mechanism responsive to the position of said movable element for effecting the advance of said element from a starting position at different speeds and its retraction from a predetermined advanced position, a switching valve operative to secure the advance of said movable element from its starting position, a second switching valve operative to secure the advance of said movable element at slow speed, a third switching valve operative to control admission of actuating fluid to said valve mechanism, a fourth switching valve operative to effect retraction of said movable element, a manually operated valve member controlling the operation of at least certain of said switching valves, and switching valve mechanism operative to establish different operative relations between said switching valves and said manually operated valve member to effect different operations of said movable element.

40. In a drilling machine, a drill, a work support, one of the aforesaid elements being movable relatively to the other element, a hydraulic motor for moving said movable element, a source of actuating fluid, valve mechanism controlling fluid flow between said motor and source including a shiftable valve member having a neutral position corresponding to the retracted condition of said movable element and other positions operative to secure retraction and fast and slow advance of said movable element, cam means movable relatively to said valve member for effecting movement of said valve member into such different positions, means constantly biasing said valve member for movement away from said cam means, hydraulic means for moving said valve member against the action of said biasing means into engagement with said cam means, a starting valve for effecting the actuation of said hydraulic means to move said valve member from its neutral position into another position, said valve member having means operative in said other position to maintain said hydraulic means actuated, and means to effect the momentary operation of said starting valve having means to hold said starting valve in operated position for a period of time sufficient to permit the move-

ment of said movable valve member away from neutral position.

41. In a drilling machine, a drill, a work support, one of the aforesaid elements being movable relatively to the other element, a hydraulic motor for moving said movable element, a source of actuating fluid, valve mechanism controlling fluid flow between said motor and source including a shiftable valve member having a neutral position corresponding to the retracted condition of said movable element and other positions operative to secure retraction and fast and slow advance of said movable element, cam means movable relatively to said valve member for effecting movement of said valve member into such different positions, means constantly biasing said valve member for movement away from said cam means, hydraulic means for moving said valve member against the action of said biasing means into engagement with said cam means, a starting valve for effecting the actuation of said hydraulic means to move said valve member from its neutral position into another position, said valve member having means operative in said other position to maintain said hydraulic means actuated, a time delay valve having connections with said starting valve for effecting energization of said starting valve through said time delay valve, said time delay valve having means for effecting the slow movement thereof into an operated position and said time delay valve when in fully operated position effecting the return of said starting valve to an unoperated position, and means for initiating the operation of both valves conjointly.

42. In a drilling machine, a movable element, means including a hydraulic motor for effecting fast and slow and also retraction movements of said element, means including a throttle valve for effecting slow advance of said element, cam operated reversing valve mechanism controlling the movements of said element and having neutral, fast advance, slow advance and retraction positions corresponding to corresponding conditions of said movable element, a manually operated valve member controlling operation of said element, a switching valve controlling the operative and inoperative positions of said throttle valve, means establishing both said manually operated valve and said throttle valve in control of said throttle valve through said switching valve, and selector valve means operative to establish control of said throttle valve by said manually operated valve and separately by said reversing valve.

43. In a drilling machine, a drill, a work support, means including a hydraulic motor for effecting movement of one of said aforesaid elements relatively to the other element, a main control valve in control of said motor having a neutral position where said motor is stationary and two different positions setting said motor for fast advance and retraction movement of said movable element, a throttle valve also in control of said motor having an inoperative position and a position setting said motor for slow advance of said movable element, hydraulically operated valve setting means for said main valve and for said throttle valve, cam operated valve mechanism in control of said valve setting means and including a valve member having a neutral position where the movable element is stationary in retracted position and fast advance, slow advance and retraction positions, a manually operated valve member controlling the operation of said movable element, a plurality of switching valves some controlled by said manually operated valve member and some controlled by said movable valve member for effecting control of said valve setting means, and selector valve mechanism for shifting control of said switching valves by the aforesaid members for effecting operation of said movable element under different conditions.

44. In a drilling machine, a drill, a work support, means including a hydraulic motor for effecting movement of one of said aforesaid elements relatively to the other element, a main control valve in control of said motor having a neutral position where said motor is stationary and two different positions setting said motor for fast advance and retraction movement of said movable element, a throttle valve also in control of said motor having an inoperative position and a position setting said motor for slow advance of said movable element, hydraulically operated valve setting means for said main valve and for said throttle valve, cam operated valve mechanism in control of said valve setting means and including a valve member having a neutral position where the movable element is stationary in retracted position and fast advance, slow advance and retraction positions, a manually operated valve member controlling the operation of said movable element, a plurality of switching valves some controlled by said manually operated valve member and some controlled by said movable valve member for effecting control of said valve setting means, and selector valve mechanism for shifting control of said switching valves by the aforesaid members for effecting operation of said movable element under different conditions, and having a position wherein maintenance of said manually operated valve member in operated condition effects the continuous reciprocation of said movable element.

45. In a drilling machine, a drill, a work support, means including a hydraulic motor for effecting movement of one of the aforesaid elements relatively to the other element, a source of actuating fluid, valve mechanism operative to control the flow of fluid between said motor and source, cam mechanism normally operative in response to the position of said movable element to control said valve mechanism to effect a predetermined manner of operation of said motor and of said movable element, selector valve means associated with said valve mechanism and operative to vary the aforesaid manner of operation of said motor and of said movable element, and pedal-controlled means operative to dominate the control of said motor and movable element irrespective of the manner of operation thereof as determined by said selector valve means.

46. A drilling machine as in claim 45, the pedal-controlled means including a single pedal having means operated thereby to initiate and control the progress of any selected manner of operation of said motor and movable element.

47. In a drilling machine, a drill, a work support, means including a hydraulic motor for effecting movement of one of the aforesaid elements relatively to the other element, a source of actuating fluid, valve mechanism operative to control the flow of fluid between said motor and source, cam mechanism normally operative in response to the position of said movable element to control said valve mechanism to effect a predetermined manner of operation of said motor and of said movable element, selector valve means as-

sociated with said valve mechanism and operative to vary the aforesaid manner of operation of said motor and of said movable element, a control pedal, and means responsive to an initial depression of said pedal to effect the operation of said motor and movable element to control the progress of any selected manner of operation thereof, and responsive to a second depression of said pedal to effect the retraction of said movable element.

48. In a drilling machine, a drill, a work support, means including a hydraulic motor for effecting movement of one of the aforesaid elements relatively to the other element, a source of actuating fluid, valve mechanism operative to control the flow of fluid between said motor and source, cam mechanism operative to control said valve mechanism to provide a predetermined cycle of operation of said motor and movable element, selector valve means associated with said valve mechanism to modify said cycle and to provide different cycles of operation, and pedal controlled means controlling the operation of said movable element in said various cycles.

49. In a drilling machine, a drill, a work support, means including a hydraulic motor for effecting movement of one of the aforesaid elements relatively to the other element, a source of actuating fluid, valve mechanism operative to control the flow of fluid between said motor and source, cam mechanism operative to control said valve mechanism to provide a predetermined cycle of operation of said motor and movable element, selector valve means associated with said valve mechanism to modify said cycle and to provide different cycles of operation, and pedal controlled means controlling the operation of said movable element in said various cycles, said pedal controlled means including a single pedal and means associated therewith responsive to an initial depression of the pedal to effect control of the advance of said movable element in any selected cycle and responsive to a second depression of said pedal to secure retraction of said movable element.

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