

May 17, 1938.

M. S. CURTIS

2,118,025

MACHINE TOOL, PARTICULARLY OF THE HYDRAULIC OPERATED TYPE

Original Filed June 29, 1932 5 Sheets-Sheet 1

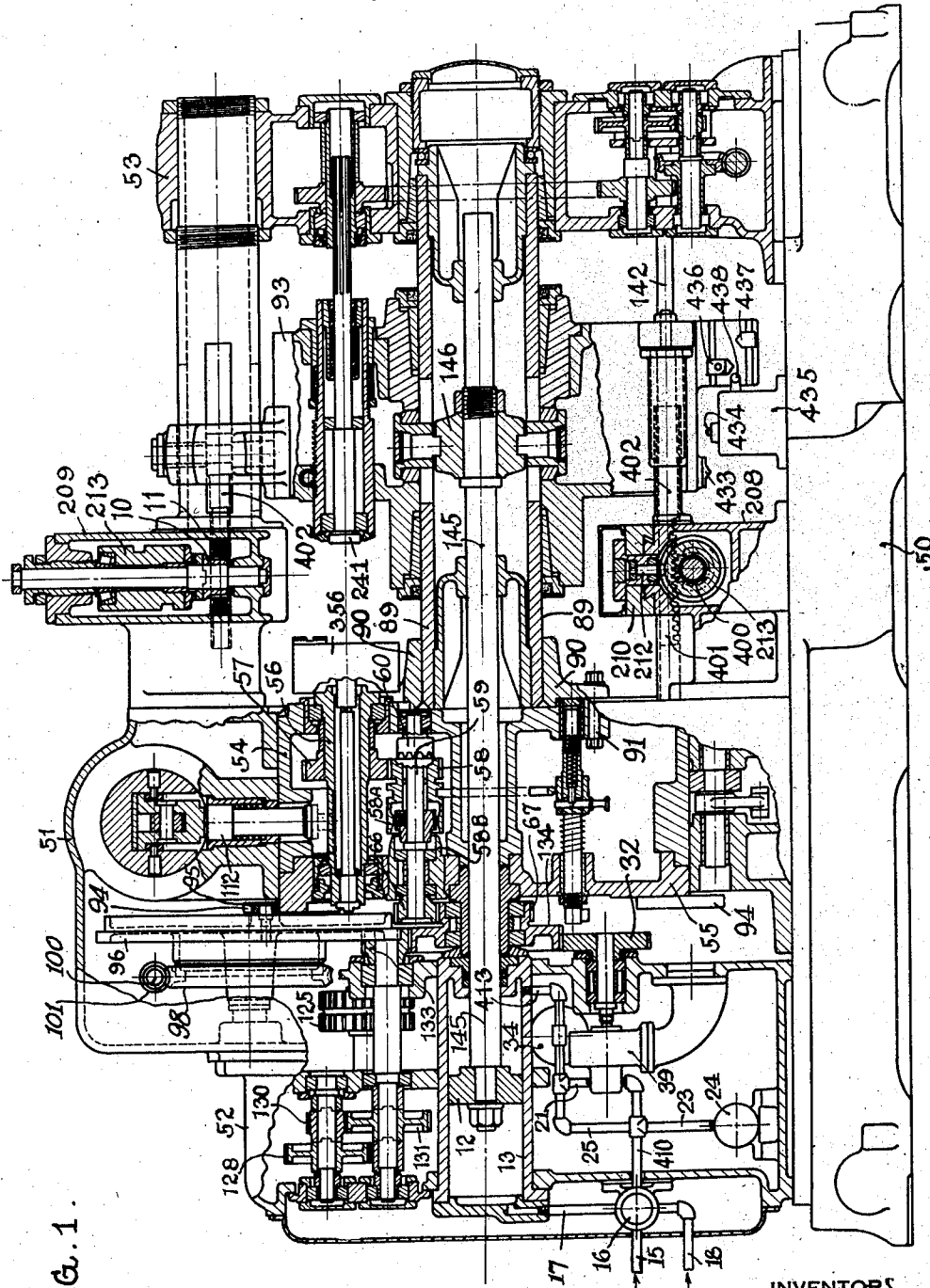


FIG. 1.

INVENTORS

BY *M. S. Curtis,*
Chas. Williamson,
ATTORNEY

May 17, 1938.

M. S. CURTIS

2,118,025

MACHINE TOOL, PARTICULARLY OF THE HYDRAULIC OPERATED TYPE

Original Filed June 29, 1932

5 Sheets-Sheet 2

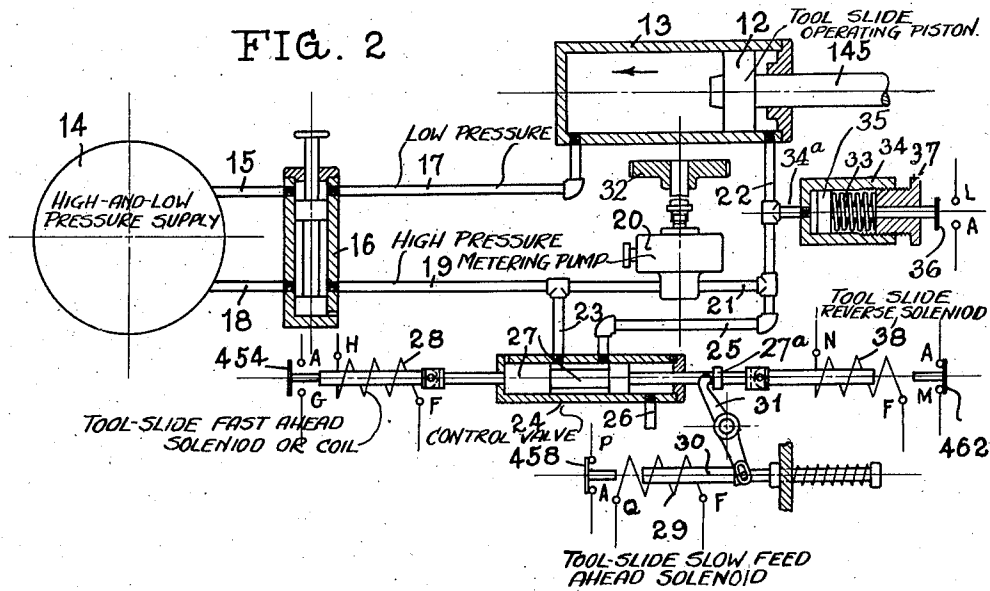


FIG. 3.

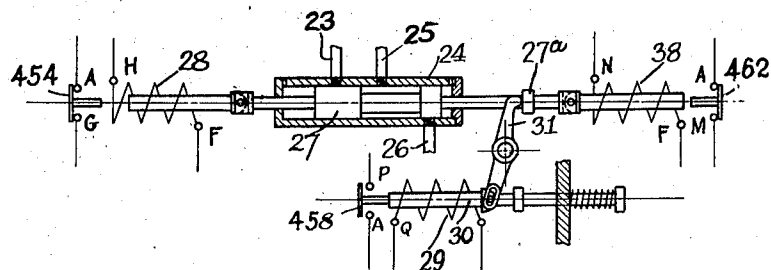
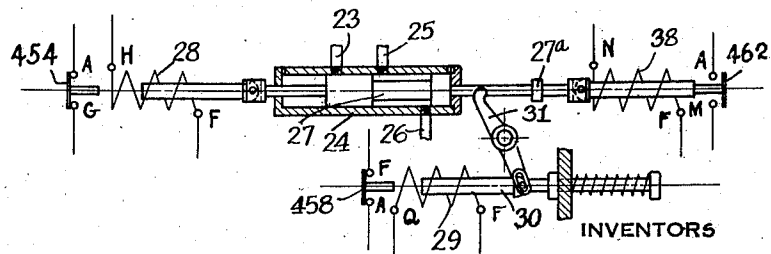


FIG. 4



INVENTORS

BY *M. S. Curtis*
Chas. Williamson
ATTORNEY

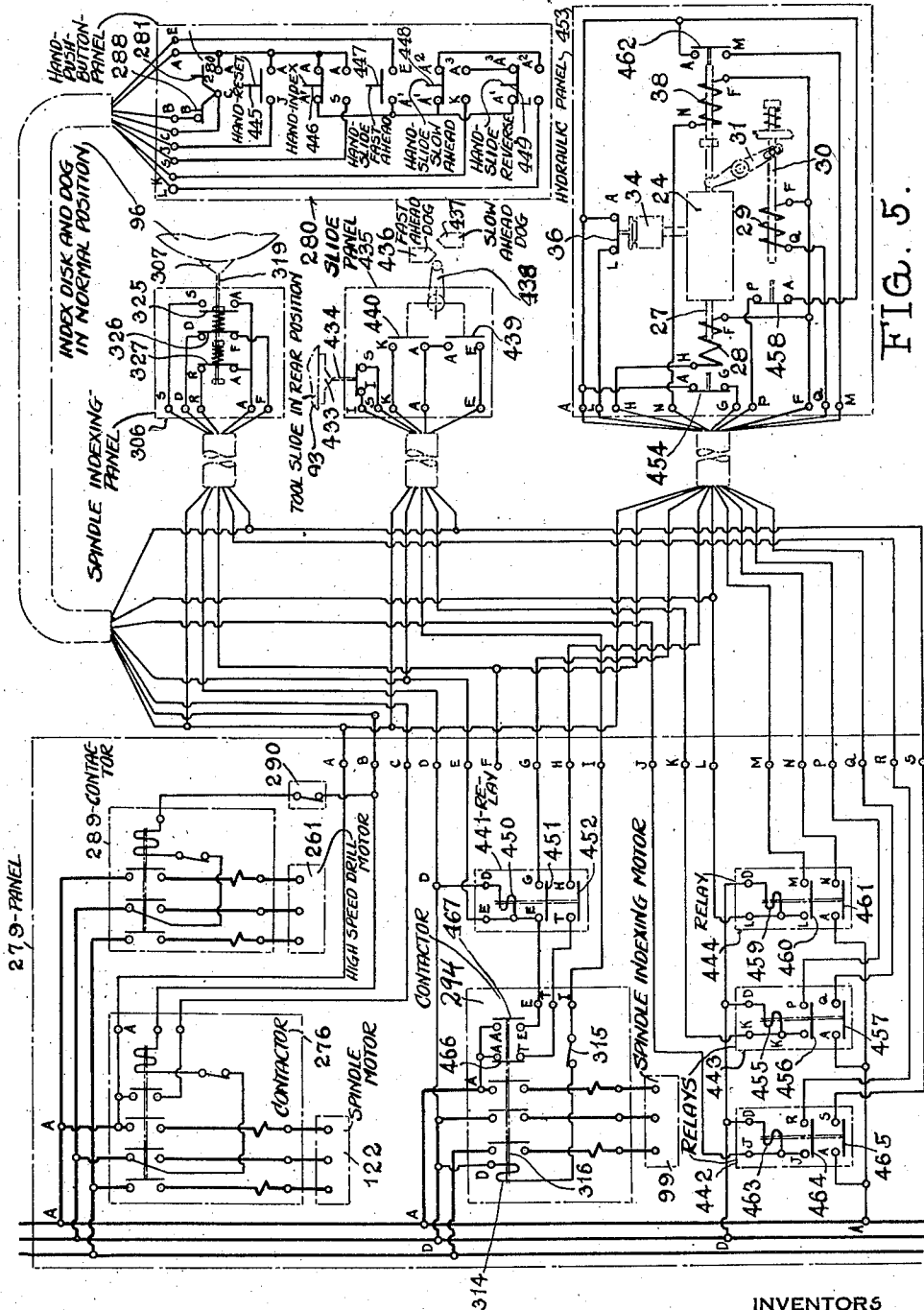
May 17, 1938.

M. S. CURTIS

2,118,025

MACHINE TOOL, PARTICULARLY OF THE HYDRAULIC OPERATED TYPE

Original Filed June 29, 1932 5 Sheets-Sheet 3



INVENTOR 5

By *M. S. Curtis*
Charles Williams
ATTORNEY

May 17, 1938.

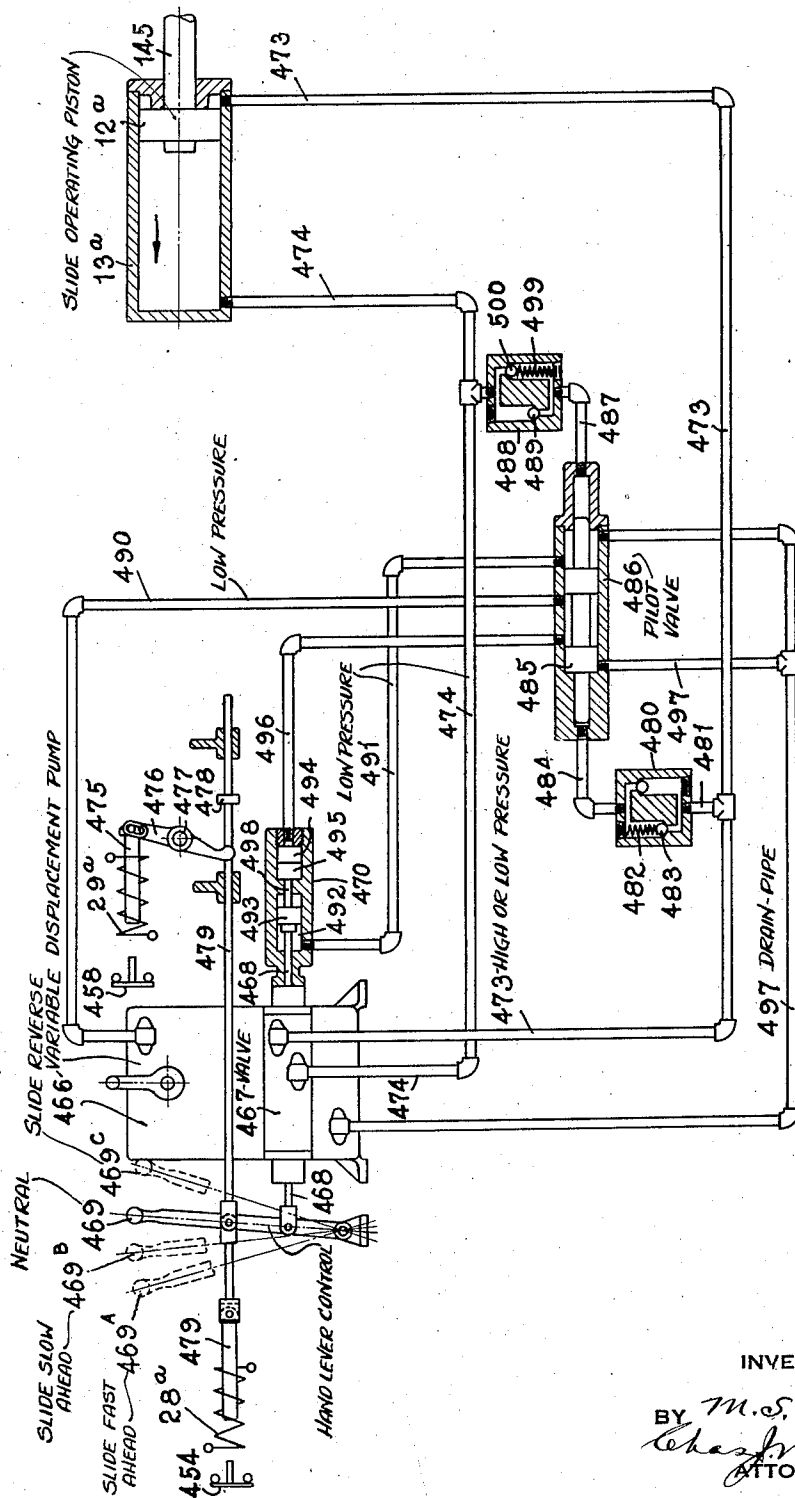
M. S. CURTIS

2,118,025

MACHINE TOOL, PARTICULARLY OF THE HYDRAULIC OPERATED TYPE

Original Filed June 29, 1932 5 Sheets-Sheet 4

FIG. 6.



INVENTORS

BY *M. S. Curtis*
Chas. Williamson
ATTORNEY

May 17, 1938.

M. S. CURTIS

2,118,025

MACHINE TOOL, PARTICULARLY OF THE HYDRAULIC OPERATED TYPE

Original Filed June 29, 1932

5 Sheets-Sheet 5

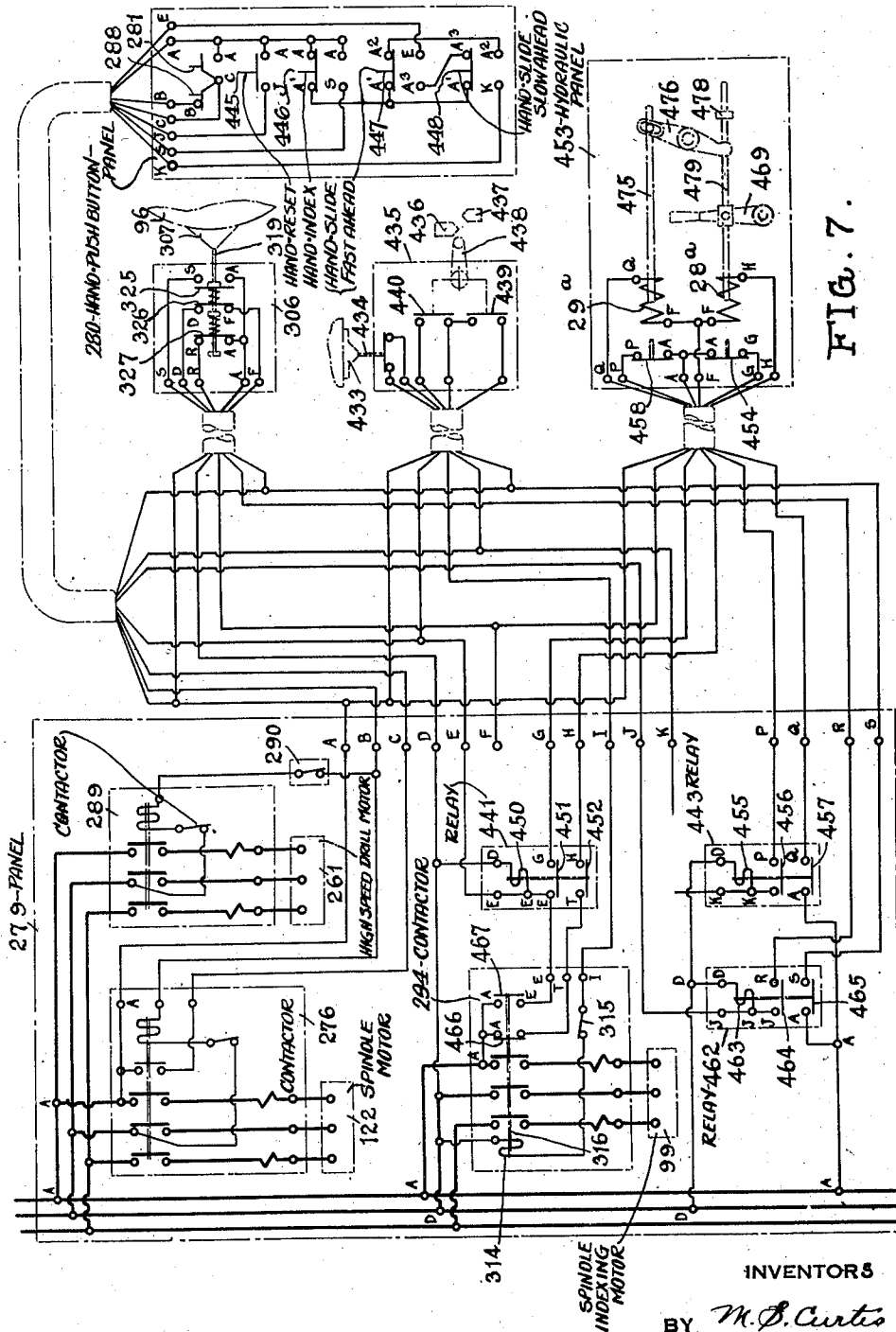


FIG. 7.

INVENTOR

BY *M. S. Curtis*
Chapman & Williamson
ATTORNEY

UNITED STATES PATENT OFFICE

2,118,025

MACHINE TOOL, PARTICULARLY OF THE
HYDRAULIC OPERATED TYPEMyron S. Curtis, Pawtucket, R. I., assignor to
William Wallace Potter, Pawtucket, R. I.Application June 29, 1932, Serial No. 620,022
Renewed April 17, 1937

20 Claims. (Cl. 29—35)

The invention relates to machine tools, wherein there are coacting work-piece carrying members and tool carrying members.

In the production of the invention, I have adapted or embodied it in a station type multiple spindle machine, such as forms the subject of my joint copending application No. 542,156 and, because of special advantages in such a machine of that type, I illustrate and describe the invention with that type of machine, but this is by way of exemplification or illustration of the invention and not limitation or restriction of the scope thereof.

One of the particular objects of the invention is the hydraulic operation of the tool slides, so that in a machine of the work-carrying spindle type, there will be such control of the pressure, especially for tool feed, that the ratio of tool feed to spindle revolution will be maintained at all times.

Other objects and advantages of the invention will be evident from the description which is given in the following specification.

The invention consists in whatever is defined by or is included within the terms or scope of the appended claims.

In the drawings:

Fig. 1 is a longitudinal section of a machine embodying the invention;

Figs. 2, 3 and 4, are respectively, views of the hydraulic feed mechanism, with the operating valve in three different positions;

Fig. 5 is a diagrammatic view of the electrical control and interlocks;

Fig. 6 is a diagrammatic view of an alternative hydraulic system;

Fig. 7 is a diagrammatic view of the electric connections and interlocks for operating the hydraulic system shown in Fig. 6.

The embodiment of the invention appearing in the drawings has the desirable characteristics in a machine in which the tool slide or slides are hydraulically operated, the fluid under high and low pressure is furnished to the slide operating mechanism from an outside source, the high feeding pressure accurately metered in relation to the spindle rotation of the machine for the purpose of feeding so that the feed is synchronous with the spindle revolutions; the hydraulic operations are under remote electric control; and feed control, and control of other functions of the machine are interlocked.

For the purpose of simplifying illustration of drawings and description of this specification, the parts of the machine illustrated in the ac-

companying drawings which are similar to or correspond with those of the aforesaid application, will be given the same reference numerals which are used in that application.

Referring to Fig. 1, base 50 has bolted to it in alignment spindle carrier housing 51, gear housing 52, and a rear housing 53. Housing 51 has revolvably located in it spindle carrier 54 provided with an end plate 55 and carrying suitably supported in it a plurality of work carrying spindles 56, preferably spaced around the axis of the carrier 54. Spindle carrier 54 may be indexed in a step by step manner by motor 99 (see Fig. 5) which rotates shaft 101 carrying worm 100, (Fig. 1) meshing with a worm gear 96 on an index disk 96. The disk 96 carries a roll 95 which successively engages in equi-spaced slots 94 provided in the spindle carrier and plate 55 after the manner of the well known Geneva movement. The spindle carrier 54, when thus indexed, is located and securely clamped by locking pins 112. Spindles 56 are driven by motor 122 (see Fig. 5) connected with chain sprocket 125, and from the latter through a set of change gearing (gears 128, 130 and 131, pinion 133 and double gear 134 and 67, pinion 66, shaft 58, clutch 60 which drives gear 57 on the spindle 56) shown in Fig. 1; there being parts 66, 58, 60 for each spindle and each spindle may be stopped and braked, while at the loading station, through internal cone 58a clutch pinion 59 and fixed external cone 58b. The method of driving the spindles, clutching and declutching the same, operating the work holding fixtures or chucks 356 and indexing and clamping the spindle carrier 54 are all fully described in said copending application 542,156, and form no part of this invention.

Carrier 54 has axially bolted to it a tube 89 by means of a flanged collar 90 shrunk or welded on the tube 89 and fastened to the carrier 54 by bolts 91. Slidable on the tube 89 is tool carrier 93, which may be slid back and forth on tube 89 by thimble 146 fastened to rod 145 for the purpose of performing work, this motion being imparted from rod 145 to slide 93 for the purpose of reciprocating the latter. Slide 93 carries necessary tools for operating upon work held in fixtures or chucks 356 and may have mounted thereon the including rotary tool holder, 241. The construction and operation of carrier 93 and rotary tool holder 241 are fully described in my copending application and, as they form no part of this invention, I do not further describe the same.

Fastened to housing 51 are cross slide bases 55

208 and 209 which carry cross slides 210 operated by cam 213 through cam roll 212, as described in my said copending application.

Cam 213 has clutched to it spur gear 10 with which teeth of rack bar 11 mesh. Rack bar 11, is fastened to main tool slide 93 so that, as the latter advances and returns, rack bar and gear oscillate cam 213, and thereby advance or return cross slide 210. Thus, the cross slides as well as main tool slide 93 receive their motion from the primary operating rod 145.

Fastened to one end of rod 145 is piston 12 slidable in cylinder 13. Referring to Figs. 2, 3 and 4, it will be seen that an accumulator 14 or other suitable means furnishes fluid at a low pressure through pipe 15, cut-off valve 16, and pipe 17 to the return end of cylinder 13; and it also furnishes fluid under high pressure through pipe 15, stop valve 16, pipe 19, to metering pump 20 and thence through pipes 21 and 22 to the feed end of cylinder 13. The cut-off valve 16 simultaneously connects or disconnects the high and low pressure with or from the machine. A branch pipe 23, leads from pipe 19 to control valve 24, another branch pipe 25 leads from pipe 21 to control valve 24 and a pipe 26 leads from control valve 24 to the drain.

Control valve 24 contains a piston valve 27, which, when solenoid 28 is energized, is pulled into the position shown in Fig. 2, the solenoid circuit being hereafter explained. When in this position, high pressure fluid flows from the accumulator through pipe 18, stop valve 16, pipe 19, pipe 23, through valve 24, pipe 25, pipe 22 to the feed end of cylinder 13 in large volume. It also flows from pipe 19, to pipe 21, through metering pump or valve 20. Low pressure fluid is always supplied to the return end of the cylinder 13 from accumulator 14, but the low pressure resistance on the return side is overcome by the high pressure on the feed side and, therefore, piston 12, and consequently the slide reciprocating rod 145, is advanced rapidly in the direction of the arrow in Fig. 2, thereby advancing rapidly main slide 93 and cross slides 210 to their cutting positions. When this position is reached, solenoid 29 is energized in a way hereinafter to be described, and by plunger 30 operating lever 31, which engages on a collar on the valve rod, moves valve 27 to the position shown in Fig. 3. When the valve 27 is in this position, high pressure fluid cannot flow directly from pipe 23 to pipe 25, but must go through metering pump 20, (which pump is of a well known multipiston variable stroke type and is furnished with a gear 32 driven from gear 134, see Fig. 1, and consequently metering pump 20 rotates in synchronism with the spindles 56, because pump and spindles are geared together). High pressure is now supplied in a small metered amount to the feed side of piston 12 (overcoming the resistance of the low pressure on the return side of the piston) and consequently the various tool slides are given their feed motion on the work at a measured rate synchronously, or in time with the spindle revolutions. The rate of feed is alterable by varying the stroke of the metering pump 20.

When the slide reaches the limit of its feed stroke, tool slide 93, is brought to a positive stop by stop rod 142, as in said copending application, and piston 12 discontinues its work operation feed movement. Pressure immediately begins to rise in pipe 22, until it reaches a degree to overcome the resistance of spring 33, in a cylinder 34,

acting on a piston 35 therein, cylinder 34 being connected to pipe 22 by pipe 34a. Pressure over the resistance of spring 33 causes piston 35 to move and thus close a control circuit by a switch 36 connected with said piston 35. The strength of the spring 33 may be varied by an adjusting nut 37. The time for piston 35 to move enough to close the circuit gives a desirable delay at the end of the feed stroke. The circuit closed by switch 36 excites solenoid 38, as hereinafter described, which latter pulls valve 27 to the position shown in Fig. 4. The feed side of cylinder 13 is now connected directly with drain pipe 26 through pipes 22 and 25, and all pressure on the feed side of piston 12 is removed. As low pressure is maintained on the return side of the piston 12, it, together with the attached slides, being returned rapidly to the starting point.

The operation of the solenoids, for controlling the hydraulic feed, together with their interlocks, by the outer elements of the machine is diagrammatically shown in Fig. 5. In this diagram, as in the aforesaid application, the terminals are designated by letters, and terminals with like letters are always connected. It will be noted that terminal A is always connected with one wire of the main line and the terminal D is always connected with a ground wire of the main line so that, when A and D are connected, a current flows through the circuit.

Contactors 276 on panel 279 operates spindle motor 122 and contactor 289 operates high speed drill motor 261, through push buttons 281 and 288; and a cutout switch 290 is furnished for contactor 289 in the same manner as in said copending application, and therefore requires no further explanation.

The contactor 294 controls index motor 99—the functions of this motor being to revolve index disc 96 which controls the indexing and locking of the spindle carrier 54, as in said copending application, and the movements of this index disc 96 must be interlocked with movements of the slide 93. For this purpose I provide on index disc 96 a dog 307 which operates plunger 319, thereby operating switches 325, 326 and 327 so that, when disc 96 has completed all the functions incidental to indexing the spindle carrier 54, the dog 307 pushes plunger 319 in, switch 327 first closes circuit between A and R; switch 326 then closes circuit between F and D; switch 325 then breaks the circuit between A and S, and when dog 307 moves away from plunger 319, it permits the reverse operation to take place,—namely: switch 325 first closes circuit between A and S; switch 326 then breaks the circuit between F and D; and switch 327 breaks the circuit between A and R. On the main tool slide 93 is a fixed dog 433, which, when the slide 93 reaches its extreme rear position, operates switch 434 in contactor 435 to close the circuit between I and S and, when in any other position, switch 434 breaks the circuit between I and S. Also on slide 93 are adjustable dogs 436 and 437 which by acting on arm 438 close, respectively, normally open switches 439 and 440, thus completing the circuits between A and E, and A and K, respectively. I also provide on panel 279 relays 441, 442, 443 and 444, the functions of which will be hereinafter described, and on push button panel 280 is a reset switch 445, a hand index switch 446, a fast ahead hand switch 447, a slow ahead hand switch 448, and a reverse hand switch 449.

The machine illustrated may be operated or controlled by hand or automatically. The hand

operation, which I will first describe, is accomplished by hand push buttons 446, 447, 448 and 449. It must be made impossible to index the spindle carrier except when the tool slide 93 is in its extreme rear position, and it must be impossible to operate tool slide 93, except when the index is stopped in such a position that dog 307 has pushed in plunger 319 and this must be so both in hand operation, and in automatic operation. To operate the index by hand, push button 446 is depressed. This first breaks the connection between A and the slide operation push buttons, thus preventing their operation; it next connects A and S and, if slide 93 is in its extreme rear position so that dog 433 closes switch 334, current will flow from S to I in contactor 435; thence to connection I in contactor 294, through thermally operated safety switch 315 and solenoid 314 to connection D, thus forming a circuit through solenoid 314, energizing the same and closing motor switch 316, and starting motor 99 which operates disc 96. Motor 99 runs as long as button 446 is depressed and stops as it is released.

Depressing fast ahead push button 447 connects A¹ and E, and if index push button 446 is not depressed, but is in the position illustrated, current flows from A¹ to E, thence to E in relay 441, through solenoid 450 to D, thus completing a circuit through the solenoid and closing switches 451 and 452. Closing of the switch 452 allows current to flow from A in contactor 294 to T if switch 316 is open in the position shown so that motor 99 is stopped; thence to T in relay 441, through switch 452 to H, thence to H in the hydraulic panel 453 (includes parts shown in Fig. 2) through fast ahead solenoid 28 to F, thence to F in contactor 306 and through switch 326 to D, providing switch 326 is closed by index disc being in a position so that dog 307 is holding in plunger 319. This completes the circuit through solenoid 28, thus operating valve 27 to the position shown in Fig. 2 and starting the slide fast ahead. The pulling of valve 27, to the left by solenoid 28, causes the valve rod to operate switch 454 breaking the circuit between A and G.

The slow speed is operated by depressing button 448. This first breaks the connection between A¹ and A² thus cutting off current from the reverse switch 449, then completes the connection between A³ and K if switch 449 is in its inoperative position as shown, causing current to flow to K in relay 443 thence through coil 455 to connection D. This energizes coil 455 and closes switches 456 and 457. Closing of the switch 456 allows a holding circuit to flow from A to P in hydraulic panel 453, thence to P in relay 443, through switch 456 to K and thence through coil 455. Switch 457 completes a circuit from A to Q in relay 443, thence to Q in hydraulic panel 453, through solenoid 29 to F, and if as before switch 326 in contactor 306 is closed, through to D. This completes the circuit through solenoid 29, thus energizing the same and by means of rod 30, lever 31 acting on collar 27a, moves valve 27 to slow feed position shown in Fig. 3. Movement of rod 30, also causes switch 458 to break a holding circuit between A and P, thus de-energizing solenoid 455 and allowing switches 456 and 457 to open.

Depressing push button 449 closes the circuit between A² and L in panel 280, if switch 448 is in its inoperative position as shown, causing current to flow to L in relay 444, thence through solenoid 459 to D, thus energizing solenoid 459. This causes switches 460 and 461 to close. The

closing of switch 460 completes a holding circuit through solenoid 459 when switch 462 in panel 453 is closed, which is the case except when in reverse. Closing switch 461 completes a circuit between A and N, thence to N in hydraulic panel 453, through solenoid coil 38 to F and thence from F to D in panel 306 if switch 326 is closed. This completes a circuit through solenoid 38 energizing the same and pulling valve 27 to reverse position shown in Fig. 4. Valve 27 when moved to the reverse position opens switch 462 thus breaking the holding circuit through coil 459 in relay 444 and allowing switches 460 and 461 to open. It is thus seen that by the action of switches 454, 458 and 462 in hydraulic panel 453, that the circuit through the operating solenoids is broken as soon as they have completed their work.

Automatic operation.—Assume the tool slide is in its extreme rear position and a cycle of the machine has been completed, but that spindle drive is operating and the clutch or clutches 60 are disconnected. The operator chucks a piece of work, then he starts the indexing of the spindle carrier 54. At the completion of the indexing, the tool slide 93 starts forward on the fast motion until the tools reach the work, when a dog 437 on the tool slide trips the hydraulic feed into slow ahead work-operating movement. When the slide reaches the end of its stroke, the pressure built up in the feed cylinder causes the hydraulic mechanism to trip into reverse and the tool slide returns to its former position. During this time, the operator is chucking a new piece of work, as above stated, and after he has finished, he pushes the reset safety button 445, which causes the cycle to be repeated as soon as the slide reaches its extreme rear position. If he does not, however, press the reset push button 445, the machine stops until he does press this button.

The above generally described automatic cycle is accomplished thus: With the slide 93 at its extreme rear position, dog 433 will hold switch 434 closed. The indexing has stopped in such position that dog 307 on index disc 96 has pushed plunger 319 into the position shown (Fig. 5). The operator chucks a piece of work and then presses reset button 445 which makes a connection between A and J permitting current flow to J in relay 442 and through coil 463 to D, thus energizing this coil and closing switches 464 and 465. Closing switch 464 connects J and R and, as R is connected with A through 327 on panel 306, a holding circuit is formed through coil 463 so, when the operator releases button 445, coil 463 still remains energized. Closing switch 465 connects A with S and, as S is connected with I on panel 435 current flows to I of contactor 294 energizing coil 314 and closing switch 316. The closing of switch 316 opens the circuit between A and T by switch 466 and closes the circuit between A and D by switch 457. This energizes coil 450 in relay 441 and closes switches 451 and 452. As G is connected with A on hydraulic panel 453, closing of switch 451 permits a holding circuit to go through coil 450 maintaining switch 452 closed, which connects T with H, but as this circuit is broken by switch 466 on panel 294, no action takes place.

Closing switch 316 also starts motor 99 revolving to index disc 96 which moves dog 307 away from plunger 319. This allows the plunger 319 to automatically move (to the right of Fig. 5) first, to close switch 325 connecting A with

S, thereby maintaining a holding circuit through the index solenoid 314 by connections I; secondly, to open switch 326 breaking the circuit between F and D, thereby making it impossible to energize any of the hydraulic feed solenoids while the index is taking place; and, thirdly, to open the circuit between A and R by switch 327, which breaks the holding circuit through solenoid 463 of relay 442, allowing switches 464 and 465 to open. The opening of switch 464 breaks the holding circuit through solenoid 463 and the opening of switch 465 breaks a circuit between A and S, but, as A is still connected to S on panel 306, no change takes place.

As the index disc finishes its cycle or revolution, dog 307 again engages on plunger 319 to move it to the position shown in Fig. 5 by, first, closing switch 327, but no action takes place as this circuit is broken by switch 464 of relay 442. The plunger 319 then closes switch 326 connecting F and D, making it possible to energize the hydraulic solenoids, and then breaks a circuit between A and S by switch 325, which breaks the holding circuit through I of contactor 294, thus de-energizing coil 314 and allowing switch 316 to open, stopping indexing motor 99, and, therefore, index disc 96. This operation of the switch 316 also breaks the connection between A and E of contactor 294 by opening switch 467, but as a holding circuit current is flowing through E from G, the solenoid 450 remains energized; and also connects A to T by closing switch 466. This causes current to flow from A to T of contactor 294, from T to H of relay 441, thence to H on hydraulic panel 453 through solenoid 28 to F, thence from F to D on panel 306, which energizes solenoid 28 causing it to pull hydraulic valve 27 into the fast ahead position shown in Fig. 2. This movement of the valve 27 opens switch 454 on the hydraulic panel 453, thus breaking the connection between A and G and breaking the holding circuit through solenoid 450 of relay 441, allowing switches 451 and 452 to open, and de-energizing solenoid 28. The slide 93 now feeds fast ahead until dog 437 coacts with arm 438 on panel 435, which closes switch 440 connecting A with K and energizing coil 455 in relay 443. This energization of coil 455 closes switches 456 and 457 and, as A is connected with P on panel 453 by switch 458, a holding circuit is formed by the closing of switch 456 and the closing switch 457 completes the circuit between A and Q of relay 443, thence to Q in hydraulic panel 453, through solenoid 29 to F, thence to F on panel 306 and through switch 326 to D, thus energizing solenoid 29, which moves rod 30 so that it shifts valve 27, by means of lever 31 acting on collar 27a to slow feed position shown in Fig. 3. This movement of rod 30, also opens switch 458 on the hydraulic panel 453, breaking the holding circuit between A and P, allowing switches 456 and 457 of relay 443 to open, and de-energizing solenoid 29. Slide 93 now feeds slowly until it reaches the end of its working stroke when, as before mentioned, pressure begins to build up in cylinder 34, until it causes piston 35 to move switch 36 to close the circuit between A and L in hydraulic panel 453, which completes a circuit through coil 459 of relay 444, closing switches 460 and 461. As A is connected with M by switch 462 on panel 453, when the slide is in the fast ahead or slow feed positions, a holding circuit is formed by switch 460 through coil 459. The closing of switch 461 of relay 444 completes a circuit between A and N of relay 444, thence to N in panel 453, through

solenoid 38 to F, thence to D through switch 326 in panel 306. This energizes solenoid 38, causing it to pull valve 27 into reverse position as shown in Fig. 4, this latter movement opening switch 462, breaking the holding circuit through coil 459 so that switches 460 and 461 open, and de-energizing coil 38. Consequently, the high pressure in the cylinder 13 and in pipe 22 is open to drain 26, and the low pressure from the accumulator or other source flows through pipes 15 and 17 to the cylinder 13 thus rapidly returning the piston 12 and therefore the slide 93 to its rear position.

While these operations have been taking place, the operator has chucked a work piece in that spindle which is at the loading station and, upon completion of chucking, presses the hand reset push button 445, which connects A with J, thus energizing coil 463 of relay 442, closing switches 464 and 465. The closing of switch 464 completes a holding circuit through coil 463, by connections A and R on panel 306. The closing of switch 465 connects A with S of relay 442 but, as this circuit is broken by switch 434 on panel 435, no action takes place. When, however, slide 93 reaches its extreme rear position, switch 434 is closed by dog 433, completing the circuit from S to I, thence to coil 314 on contactor 294, thus starting the index disk 96 and then the cycle is repeated.

Should the operator, however, fail to press reset button 445, the coil 463 of relay 442 is not energized. Switches 464 and 465 remain open so that, when dog 433 closes switch 434 as the slide reaches its extreme rear position, no indexing takes place as the circuit is broken by switch 465 of relay 442. As soon as the operator energizes coil 463 by pressing hand reset push button 445, index takes place and the cycle repeats.

It may be desirable to feed the slide 93 "fast ahead" after dog 437 has thrown the feed into slow ahead. This is accomplished by dog 436, which moves arm 438 to close switch 439, making a connection between A and E, energizing coil 450 of relay 441 which closes switch 452, thus energizing "fast ahead" solenoid 28.

In Fig. 6, there is shown another hydraulic feeding system operated electrically, as shown diagrammatically in Fig. 7. In this case, there is utilized as a source of hydraulic power a variable displacement pump unit 466, similar, for instance, to that manufactured by the Oilgear Company, the construction of which is well known to the art, and driven by a motor not shown. It has a valve 467 with a valve rod 468, which can be operated by a hand lever 469 or hydraulically. When handle 469 is in the position 469a, the hydraulic feed is on fast ahead, with the handle in the position 469b it is on slow ahead, with the handle in the position 469c, it is in feed reverse, and when in the position 469, it is in neutral. Besides hand and hydraulic operation of this valve 467, there is provided electrical operation. The pump unit 466 has a variable stroke, high-pressure pump for feeding and a constant volume low-pressure pump for quick motions and maintaining back pressure and, when valve rod 468 is in the fast ahead position, the constant volume low pressure is forced through pipe 473 to the right hand or ahead side of cylinder 13a, and the left hand side of cylinder 13a is connected by pipe 474 with the exhaust. This causes piston 12a to be moved rapidly in the direction of the arrow and its piston rod 145 moves main tool slide 93 rapidly in its ahead direction. When the tools reach the work, solenoid 29a (Figs. 6 and 7) ener-

gized and the solenoid core 475, through lever 476 pivoted on stud 477, will engage collar 478 on rod 479 throwing valve rod 468 to place the valve 467 in feed work-operation position. In this position, the right hand side of cylinder 13a is connected with the variable feed high-pressure pump through pipe 473, and the left hand side of the cylinder is connected with the constant low-pressure through pipe 474, the difference in pressure causing piston 12a, and hence tool slide 93, to move slowly for work-operation. When slide 93 reaches the end of its feeding work-operation stroke, it is brought to a dead stop by stop rod 142 (Fig. 1) and pressure builds up in pipe 473 and consequently in valve 480, through branch pipe 481, until it is sufficient to overcome the resistance of spring 482 which holds ball valve 483 in its seat, spring 482 being calibrated to withstand any pressures necessary during work operation of the cutting tools. Liquid is then forced through pipe 484 to the left hand side of piston valve 485, in pilot valve 486. It will be observed that the right hand end of piston valve 485 is connected by pipe 487, and valve 488 to the low pressure pipe 474 by the check ball valve 489 in valve 488 and will lift from its seat under the pressure acting on piston valve 485 thus allowing valve 485 to be shifted to the right. This connects pipe 490 (which is always connected with the low pressure constant volume pump) with pipe 491 and causes low pressure to flow into chamber 492 of valve chest 470 and acts on piston 493 on valve rod 468 to force it to the right, thus moving the valve 467 and the handle 469 to neutral or tool slide reversing positions as will now be described.

Chamber 494 of valve chest 470, in which piston 495 is disposed, is connected by means of pipe 496 with drain pipe 497 through pilot valve 486, so that piston 493 can move to its extreme right hand position. Piston 495 has a rod 498 extending from it which abuts against piston 493 (but is not fastened to it) so that piston 495 is moved by piston 493 in its movement towards the right, but is left by piston 493 when the latter moves to its extreme left position.

Movement of piston 493 to its extreme right position throws valve rod 468 to place its valve 467 in the reverse position, and in this position the left hand end of cylinder 13a is connected by pipe 474 with the low pressure constant volume pump and the right hand end of cylinder 13a is connected by pipe 473 with the drain through pipes 481, 484, pivot valve 486 and pipe 487. This causes piston 12a to rapidly move until it reaches its extreme right hand position. Pressure then starts to build up in pipe 474 until it is able to lift ball 500 against the pressure of spring 499 in valve 488, this spring being of sufficient tension to resist the pressure necessary to return the tool slide to its extreme rear position. When the pressure is sufficient to lift valve 500, the fluid flows through pipe 487 to the right hand side of valve 485 in pilot valve body 486 and as the left hand end of this valve is now connected with the drain through pipe 484, valve 488, pipe 481, and pipe 473, valve 485 is shifted to its extreme left position. Chamber 492 is now connected by pilot valve 486 with the drain through pipes 481 and 497, and low pressure is applied to chamber 494 from pipe 490 through pilot valve 486 and pipe 496, causing piston 495 to move to its extreme left hand position. As piston 495 has only half the stroke of piston 493, it forces the latter and therefore valve rod 468 into neutral position

where all pipes are filled with the same low pressure, and piston 12a remains stationary.

The cycle can now be restarted by throwing valve 468 into the fast ahead position either by hand, or automatically by energizing solenoid 28a.

Now it will be described the automatic operation in connection with Fig. 7. It will be noted that the terminal connections are lettered and, as in the other case, connections that have similar letters are always electrically connected and, as in the other embodiment of our invention, panel 279 has the contactor 276 which operates spindle motor 122 and a contactor 289 which operates high speed drill motor 261. These motors are operated by start and stop buttons 281 and 283 in panel 280 and contactor 289 may be connected or disconnected from these push buttons through switch 290. As the operation of these contactors does not form any part of this invention, no description thereof is necessary. This circuit is, like the preceding one, capable of hand or automatic control.

To index the spindle carrier 54 by hand, a push button 446 (on push-button panel 280) depressed and first disconnects A and A¹, thus preventing hand operation of the tool slide while indexing is taking place; push button 446 then connects A and S completing a circuit to S on slide panel 435 and through switch 434 to I, if tool slide 93 is in its extreme rear position, so that dog 433 closes switch 434; thence to I on contactor 435, through thermal safety switch 315 on contactor 294 and solenoid coil 314 to D. This energizes coil 314, which operates switch 316 starting motor 99, which continues to run as long as button 446 is depressed and stops upon the release of said button. As soon as index motor 99 starts to revolve, index disc 96 moves away from plunger 310 allowing switch 326 to break the connection between D and F on panel 306, preventing feed being operated while the indexing is being performed.

To start the machine on fast motion, push button 447 is depressed, which first breaks the connection from A¹ to A² thus preventing the slow speed switch 448 from being operated and, then connected A² with E, if the tool-slide slow feed push button 448 is in its upward or release position. This completes a circuit from A to E, thence to E on relay 441, through coil 450 to D, thus energizing coil 450 which closes switches 451 and 452. Closing switch 451 completes a holding circuit through coil 450 (if G is connected with A on the hydraulic panel 453, and the closing of switch 452 connects T with H and as T is connected with A in contactor 294, current flows to H on the hydraulic panel 453, thence through solenoid 28a to F, thence to F on panel 306, through switch 326 to D. This energizes coil 28a causing it to move valve plunger 463, by means of rod 479 and lever 468, to position 469^a for starting the fast ahead tool-slide feed. Rod 479, also at the end of its movement last mentioned, operates switch 454 breaking the circuit between A and G thus de-energizing coil 450 and allowing switches 451 and 452 to open, the opening of the latter de-energizing coil 28a.

The slow tool-slide feed is operated by push button 448 which, when depressed, first breaks the circuit between A¹ and A² thus preventing the operation of the high speed push button 447; and then connects A² with K, if push button 447 is in its inoperative released or upward position. This completes a circuit between A and K and 75

current passes to K on relay 443, through coil 455 thereof to D, thus completing the circuit through coil 455, if switch 458 on panel 453 is connecting A with P, and the closing of switch 5 457 completes a circuit from A to Q, thence to Q on the hydraulic panel 453, through coil 29a thereon to F, thence to F on index panel 306 and through switch 326 to D. This completes a circuit through coil 29a energizing the same and 10 causing it—by means of rod 475, lever 476 and collar 478—to operate rod 479 a sufficient distance so that it pulls handle 469 into the slow ahead position. The operation of rod 475 also causes switch 458 to open, breaking the holding circuit 15 through coil 455 allowing switches 456 and 457 to open, the opening of the latter deenergizing solenoid 29a.

When reverse by hand is desired, it is accomplished by means of hand lever 469.

20 The automatic cycle is similar to that hereinbefore described and is accomplished thus: Assuming that the slide 93 is to be at its extreme rear position with dog 433 holding switch 434 closed and the index disk 96 to be stopped in such a 25 position that dog 307 holds plunger 319 in the position shown, the operator chucks a piece of work in the spindle at the loading station and then depresses reset button 445. This connects A with J completing a circuit to J in relay 442 30 and through coil 465 thereof to D, thus energizing this coil which closing switches 464 and 465. Closing switch 464 connects R and J forming a holding circuit through coil 463 as R is connected with A on index panel 306. Switch 35 465 connects A with S causing a current to flow to S on tool-slide panel 435, thence to I, back to I on contactor panel 294, through coil 314 to D, thus energizing coil 314 and throwing switch 316. This starts index motor 99, breaks the circuit 40 between A and T and closes the circuit between A and E on contactor panel 294, which latter completes a circuit through coil 450, energizing the same and closing switches 451 and 452. Closing switch 451 completes a holding circuit through 45 coil 450 as A is connected with G on the hydraulic panel 453. Closing switch 452 connects H with T but, as this circuit is broken on contactor panel 294, no action takes place. As soon as the indexing starts, dog 307 moves away from plunger 50 319 allowing it to move with its bias to, first, close switch 325 establishing a circuit between A and S to complete a running circuit through coil 314; then causes switch 326 to break the circuit between F and D, preventing any operation 55 of the tool-slide feed, while indexing is taking place; and then causes switch 327 to open between A and R, which breaks the holding circuit through coil 463 thus allowing switches 464 and 465 to open, the latter breaking the starting circuit through coil 314.

60 As the indexing finishes, dog 307 again pushes in plunger 319 against its bias, first, connecting A with R by switch 327, but as this circuit is broken in relay 442, no action takes place; then 65 connects D with F by switch 326, permitting operation of the feed solenoids 28a; and then breaks the circuit between A and S by opening switch 325, which latter breaks the circuit through coil 314, de-energizing the same and allowing switch 70 316 to open, stopping the index motor 99. The opening of switch 316 also causes switch 467 to break the starting circuit through coil 450 and then, closes switch 466 connecting A and T, forming a circuit from A through switch 452 to 75 H on the hydraulic panel 453. Current now flows

from H through coil 28a to F, thence from F to D in panel 306, thus energizing coil 28a and, as previously explained, starting the fast ahead feed and also opening switch 454, breaking the holding circuit through coil 450 in relay 441, al- 5 lowing switches 451 and 452 to open, the latter de-energizing coil 28a. Slide 93 is now in the fast feed ahead speed and continues so until dog 437 acts on arm 438 causing switch 440 to close the circuit between A and K on panel 435 which 10 completes a circuit to K in relay 443 and thence through coil 455 to D, energizing the coil and closing switches 456 and 457. Closing switch 456 completes a holding circuit through the coil as A is connected with P in panel 453 and the closing 15 of switch 457 completes a circuit from A to Q in panel 453, thence through coil 29a to F and from F to D in panel 306, thus energizing coil 29a and by rod 475 throwing valve rod 468 to feed ahead position. Movement of rod 475 opens 20 switch 458, breaking the holding circuit through coil 455, allowing switches 456 and 457 to open, the latter de-energizing coil 420. The tool slide then feeds ahead until it reaches the end of its stroke when the reverse is operated by the pres- 25 sure in valve 481 as hereinbefore explained. The slide then returns to its extreme rear position where it is thrown into neutral by pressure in valve 488 as before explained.

While the above described cycle has been taking 30 place, the operator chucks another piece and if after chucking the piece he depresses button 445, relay 442 is operated to complete a circuit between A and S so that when slide 93 reaches its extreme rear position and dog 433 closes switch 35 434 a circuit is completed to I, thus operating switch 316 in panel 294. This starts the index and the cycle is repeated. If the operator does not press the hand re-set button 445, thus energizing relay 442, connection is not made between 40 A and S in relay 442 and the closing of switch 434 will not start the index motor 99. The machine, therefore, remains stopped until the operator presses re-set button 445.

What is claimed is:

45 1. In a machine tool having a rotatable work spindle and means for rotating said spindle, the combination of a to and fro moving tool carrier, hydraulic means for moving the carrier to and fro 50 relative to work on the spindle, and automatic means and including elements operated by the movement of said carrier when in predetermined positions for controlling the action of the hydraulic means, said hydraulic means including a cylinder with piston fluid pressure connections 55 communicating said hydraulic means on both sides of the piston, a metering pump in at least one of said connections, and means for operating said metering pump in synchronism with the spindle, the said elements of said automatic means 60 being electrical and having operable circuit connections with a movable element of the hydraulic means.

2. In a machine tool having rotatable work-supporting spindle, the combination of a to and 65 fro moving tool carrier, a single hydraulic means for moving the carrier to and fro relative to work on the spindle, and automatic means for controlling the action of the hydraulic means, said automatic control means being electrical and including a circuit having operating connections 70 with a movable element of the hydraulic means and with a power-moved machine element that controls such circuit.

3. In a machine tool of the rotatable work- 75

supporting multi-spindle station type, the combination of a single to and fro moving tool feeding means for the tools of each spindle, hydraulic means for moving the feeding means to and fro relative to work on the spindles, means for indexing the spindles from station to station and automatic means for controlling the action of the hydraulic means and said indexing means, said automatic means including electrical circuits having interlocking elements therein that prevent concurrent action of said different members of the machine.

4. In a machine tool of the rotatable work-supporting multi-spindle station type, the combination of a to and fro moving tool carrier, a single hydraulic means for moving the carrier to and fro relative to work on the spindles, means for indexing the spindles from station to station, and automatic means for controlling the action of the hydraulic means and the indexing means, said automatic means including electrically actuated interlocking elements and actuated at predetermined positions of the tool carrier and said indexing means to prevent concurrent action of said carrier and said indexing means.

5. In a machine tool having a work-holding spindle, the combination of a to and fro moving tool carrier, hydraulic means including a pressure-receiving piston for moving the carrier to and fro relative to work on the spindle, and automatic means for controlling the action of the hydraulic means, said hydraulic means including a single source of high and low pressure supply, and high and low pressure circuit connections from the pressure supply source to opposite sides of said pressure-receiving means, a metering pump in said high pressure connection and valve means in one of said connections and controlled by the movement of said carrier for rendering the functional operations of said metering pump effective or ineffective.

6. In a machine tool having a work-holding rotatable spindle, the combination of a to and fro moving tool carrier, hydraulic means for moving the carrier to and fro relative to work on the spindle, automatic means for controlling the action of the hydraulic means including high and low pressure supply means and means for controlling the high pressure supply in a fixed relation to spindle speed and includes a metering pump operatively controlled by the spindle and further including high and low pressure circuit connections from the pressure supply means to said pressure receiving means, and valve means controlling said pressure circuit connections.

7. A machine tool comprising a rotatable work spindle, a to and fro moving tool carrier, hydraulic means for moving the carrier to and fro relative to work on the spindle including a cylinder and piston, said hydraulic means including high and low pressure supply means, and means that control high pressure supply in fixed relation to spindle speed, whereby ratio of spindle revolution and tool feed is maintained, such last-mentioned means including a metering pump operatively controlled by the spindle.

8. A machine tool comprising a work rotatable spindle, a to and fro moving tool carrier, hydraulic means for moving the carrier to and fro relative to work on the spindle and including a cylinder and piston extending axially in the direction of movement of the tool carrier, said hydraulic means including high and low pressure supply means and means that control high pressure supply in fixed relation to spindle speed,

whereby ratio of spindle revolution and tool feed is maintained, such last-mentioned means including a metering pump operatively controlled by the spindle and an operative connection between said pump and the spindle.

9. A machine tool as in claim 6 further characterized by the fluid low pressure connection being such as to operate the tool carrier in idle motions thereof, and the fluid high pressure to operate the working movement of the tool carrier.

10. A machine tool as in claim 5 in which the metering pump is driven synchronously with the spindle.

11. A machine tool as in claim 1 in which the hydraulic connections include a high and low pressure source of supply adapted to supply low and high pressure, respectively, at opposite sides of the piston, and the metering pump being in the high pressure connection between the pressure supply source and the piston, and valve means in the hydraulic means and controlled by said automatic means for selectively rendering the operation of said pressures effective or ineffective.

12. In a machine tool having a work spindle or spindles and a to and fro moving tool carrier or carriers, means for rotating the spindle or spindles, hydraulic means for moving the carrier or carriers to and fro relative to work on the spindle, said hydraulic means including a metering pump driven synchronously with the spindles, and electrically actuated automatic means for controlling the action of the functional operation of the metering pump and of the hydraulic means to effect said to and fro movement of said carrier or carriers in timed relation with the movement of said carrier or carriers, said automatic means including electrically actuated interlocking elements that prevent concurrent action of said different functional operations of said hydraulic means.

13. In a machine tool, a rotatable work-supporting spindle and a tool carrier reciprocable to and from the work on the spindle, a driving means for rotating said spindle, hydraulic means for feeding the carrier toward the work on the spindle, including a fluid supply having a metering device therein, means actuating the metering device synchronously with the spindle, whereby the feeding movement of the carrier may be maintained in constant ratio with the rotation of the spindle, a valve connected with said fluid supply and in one of its positions by-passing said metering device and in another of its positions releasing said pressure, means for moving the carrier away from the spindles when said valve is in its last mentioned position, and operatively connected interlock means whose function is determined by the position of said carrier and said valve for insuring the desired sequence of operation of the machine.

14. In a machine tool having a work rotatable spindle and a to and fro moving tool carrier, hydraulic means for moving the tool carrier to and fro relative to work on the spindle, comprising pressure circuits for moving the carrier in one direction, one of said circuits moving the carrier in fixed ratio with the spindle speed, and another circuit for moving the carrier in an opposite direction, a cylinder and a piston therein, and fluid connections extending from a hydraulic pressure source connecting the first said circuits to the cylinder at one side of the piston and to connect the last said circuit to the other side of said piston, such hydraulic circuits including a control

- valve, electrical means for moving said valve in opposite directions to change the direction of flow through said first hydraulic circuits, said electrical means including switches operated by the movement of said valve for opening and closing an operating circuit forming a part of said electrical means, and means for rendering said electrical means effective when said carrier is in certain of its positions.
15. A machine tool having a work spindle and a to and fro moving tool carrier, hydraulic means for moving the carrier to and fro relative to work on the spindle and comprising a cylinder and a piston therein and fluid connections with the cylinder at both sides of the piston, and such connections including a control valve, electrical means for moving said valve in opposite directions to change the direction of fluid flow through the hydraulic connections, said electrical means including switches operated by the movement of said valve for opening and closing an operable circuit forming a part of said electrical means, and means for rendering said electrical means effective when said carrier is in certain of its positions, the electrical means comprising means operated by the tool slide at the end of its work performing stroke for causing operation of said control valve to exhaust the work performing feeding pressure from said piston and enabling pressure on the other side of the piston to move the piston in opposite direction for reversing movement of the tool carrier, and hand re-set means for operating said control valve to supply work feeding pressure to said piston.
16. A machine tool having a work spindle and a to and fro moving tool carrier, hydraulic means for moving the carrier to and fro relative to work on the spindle and comprising a cylinder and a piston therein and fluid connections with the cylinder at both sides of the piston, and such connections including a control valve, electrical means for moving said valve in opposite directions to change the direction of fluid flow through the hydraulic connections, said electrical means including switches operated by the movement of said valve for opening and closing an operable circuit forming a part of said electrical means, and means for rendering said electrical means effective when said carrier is in certain of its positions, a device responsive to pressure on the work performing side of said piston when the tool slide has reached the end of its work performing stroke to close a circuit controlling the movement of said control valve, whereby when said circuit is closed said control valve is operated to exhaust the pressure on the work performing side of the piston, and a hand re-set means for causing said control valve to be actuated to again establish pressure on the work performing side of said piston.
17. In a machine tool as set forth in claim 14 further characterized by means operated by the tool carrier in different positions of its movement toward the spindle for actuating said control valve whereby the rate of speed of movement of the tool carrier may be varied.
18. In a machine tool having a work rotatable spindle, a to and fro moving tool carrier, means

for rotating the spindle, hydraulic means for moving the tool carrier to and fro relative to a work piece on the spindle, said hydraulic means comprising a pressure line for feeding the carrier toward the work in fixed ratio with the speed of the spindle and another pressure line for feeding the tool toward the spindle at faster speed; means for moving the tool carrier away from the spindle subordinate to said hydraulic pressures in said lines, a valve connected with said pressure lines and having ports therein for controlling the supply from said pressure lines to change the speed of movement of the work carrier toward the spindle as well as for relieving the forward feeding pressures to render them ineffective for moving the tool carrier, means for moving said valve to its various positions including means controlled by the position of said tool carrier in its forward movement, whereby either one of said pressure lines may be made effective, and automatic means rendered effective when the tool slide is at the end of its work performing movement for shifting the valve to relieve said feeding pressures, whereby the tool carrier is moved away from the spindle.

19. In a machine tool as set forth in claim 18 further characterized by indexing means for rotating parts of the machine to effect relative movement between the tool carrier and the spindle for shifting relative positions of the same, means for actuating the indexing means, means actuated by the tool carrier when in a predetermined position of its reverse movement away from the spindle for rendering operable said indexing actuating means, means actuated by the movement of the indexing means for rendering the above stated functions of the machine inoperative during the operation of the indexing means, and a hand re-set device for operating said control valve to supply a pressure for moving the tool carrier toward the spindle after the indexing operation has taken place.

20. In a machine tool having a work rotatable spindle, a to and fro moving tool carrier, means for rotating the spindle, means for moving the tool carrier to and fro relative to a work piece on the spindle including a hydraulic cylinder and piston, a source of low pressure fluid supply constantly connected to the cylinder on the side of the piston which will cause the piston to move in a direction to retract the tool carrier from the spindle, a source of high pressure fluid supply, means for connecting the source of high pressure fluid supply with the opposite end of the cylinder on the side of the piston which will cause it to move to advance the tool carrier toward the spindle, a metering device in said high pressure line driven synchronously with the spindle speed whereby the high pressure fluid may be fed to the spindle in metered amounts for performing work, a by-pass in the high pressure line whereby the metering valve may be shunted and high pressure fluid delivered to the cylinder in unmetered amounts for causing rapid movement of the tool slide toward the spindle, and means for controlling said by-pass.

MYRON S. CURTIS.