

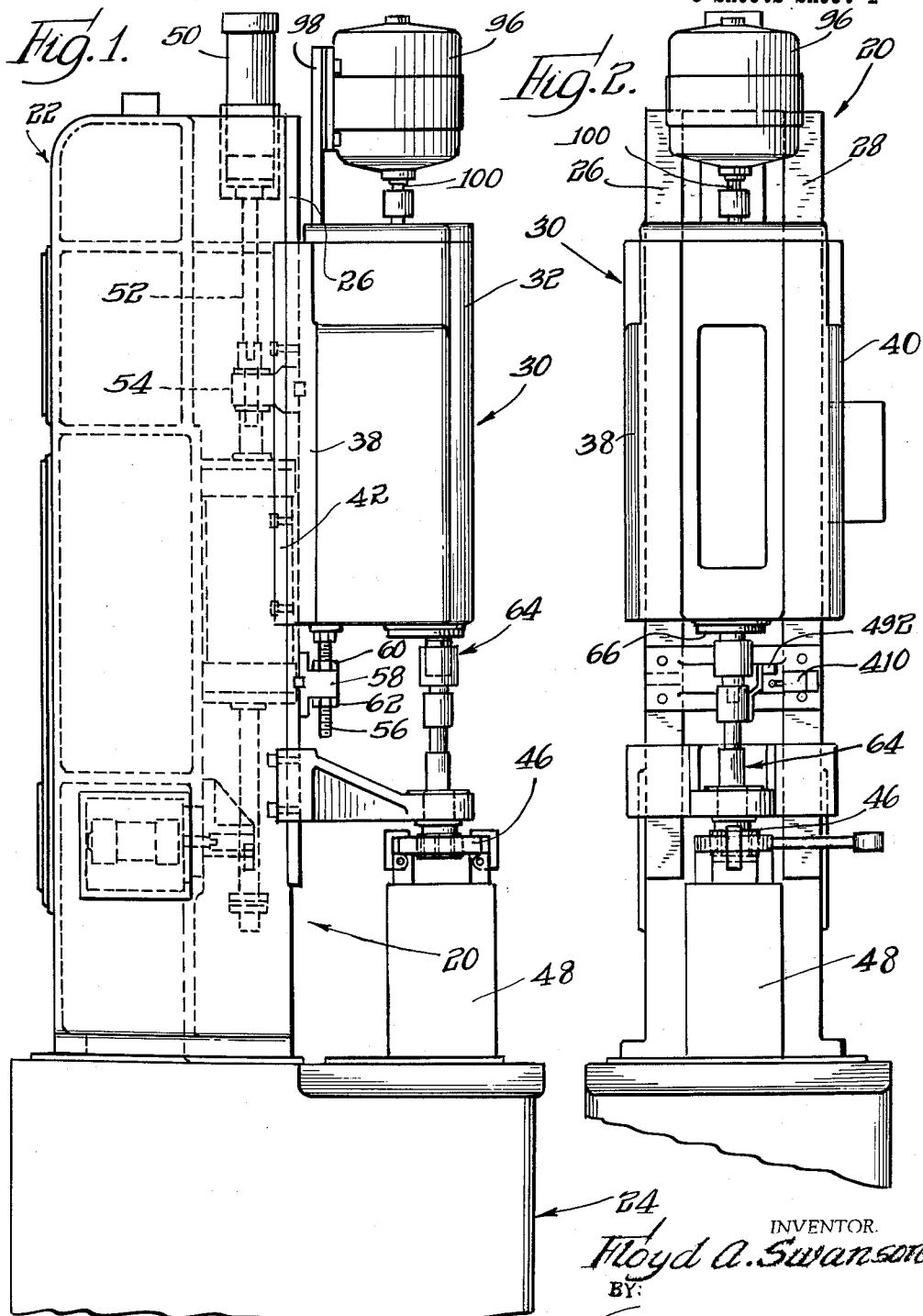
Dec. 19, 1961

F. A. SWANSON
HONING APPARATUS

3,013,363

Filed Oct. 10, 1958

6 Sheets-Sheet 1



INVENTOR.
Floyd A. Swanson
BY:
Olson & Triplett
attys.

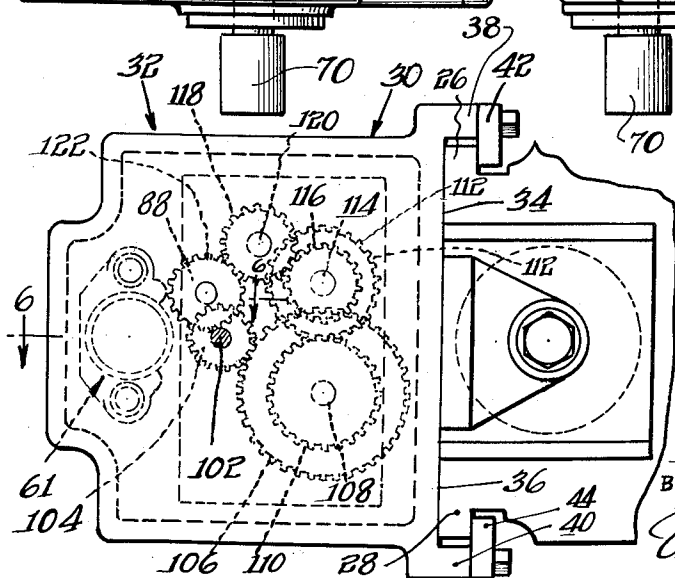
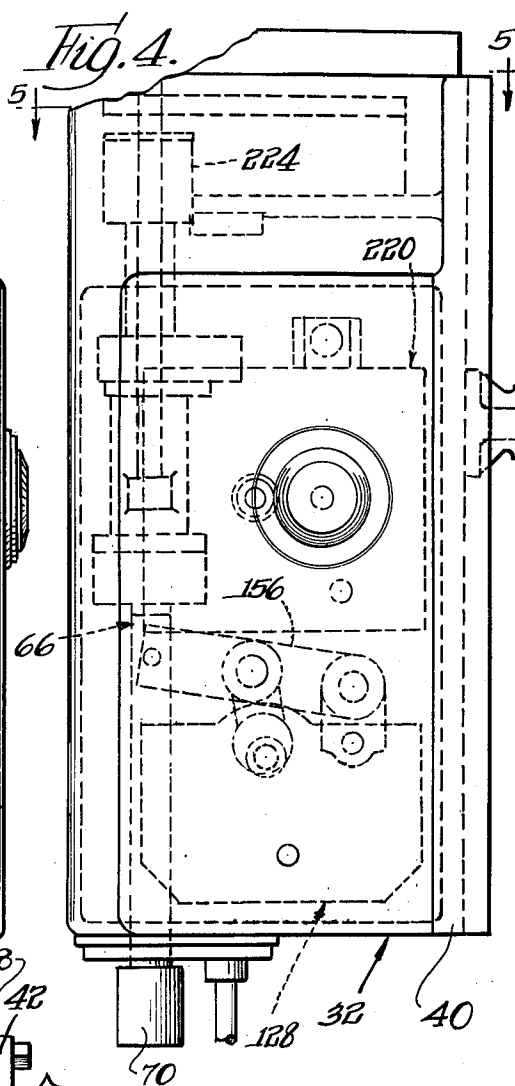
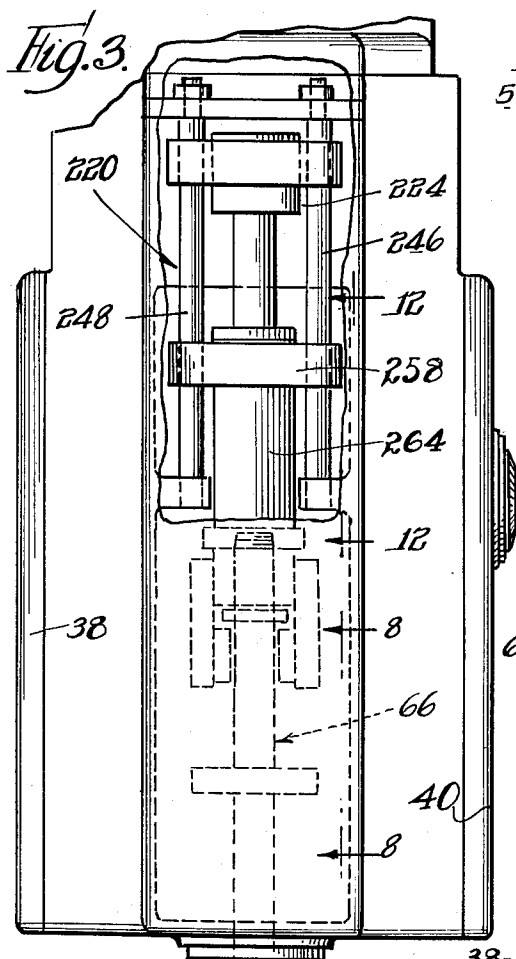
Dec. 19, 1961

F. A. SWANSON
HONING APPARATUS

3,013,363

Filed Oct. 10, 1958

6 Sheets-Sheet 2



INVENTOR.
Floyd A. Swanson
BY: *Olson & Trepner atts.*

Dec. 19, 1961

F. A. SWANSON
HONING APPARATUS

3,013,363

Filed Oct. 10, 1958

6 Sheets-Sheet 3

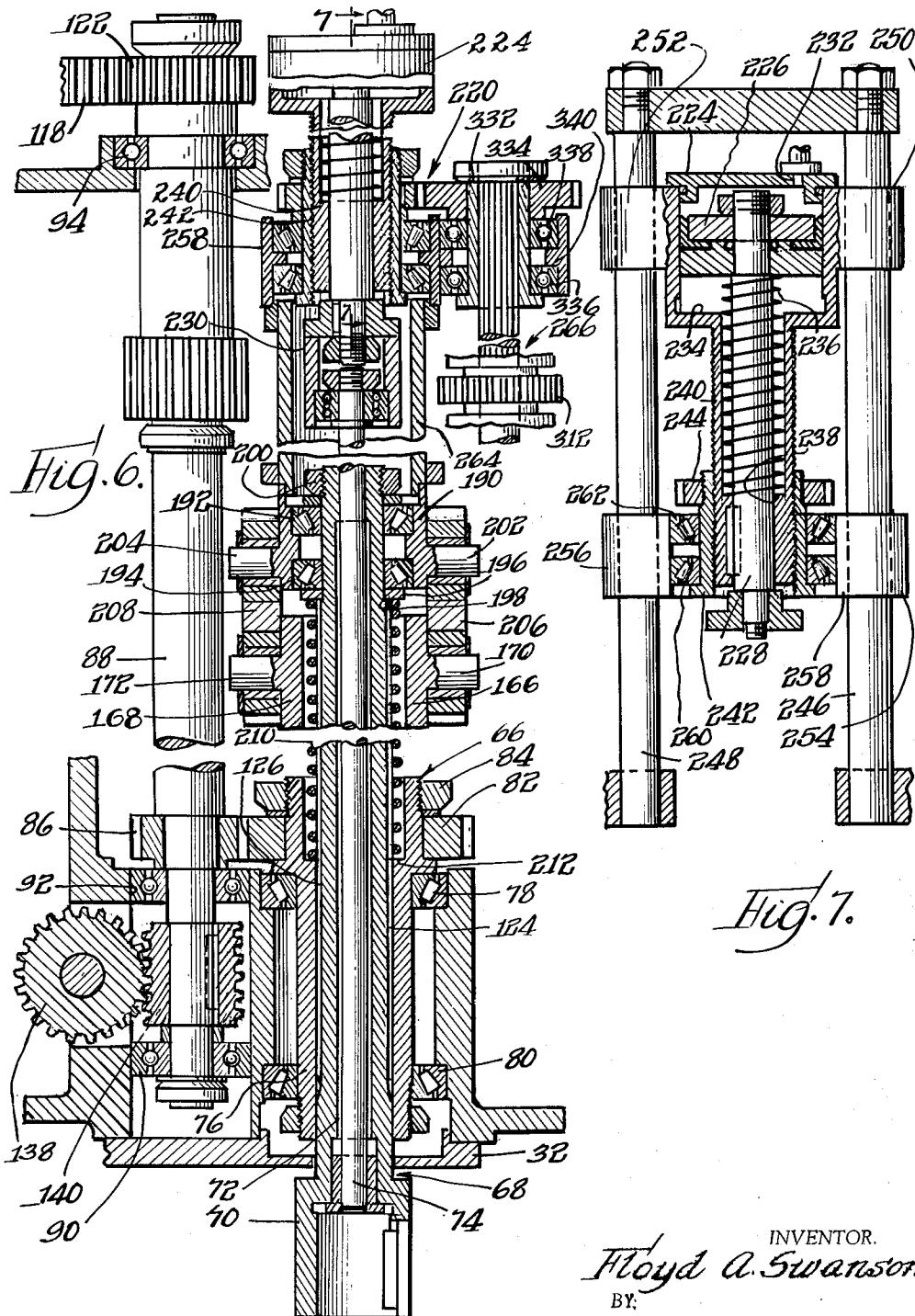


Fig. 7.

INVENTOR.
Floyd A. Swanson
BY:
Olson & Tuxley attys

Dec. 19, 1961

F. A. SWANSON

3,013,363

HONING APPARATUS

Filed Oct. 10, 1958

6 Sheets-Sheet 5

INVENTOR.
Floyd A. Swanson
BY
Olson & Tiedel attys.

Dec. 19, 1961

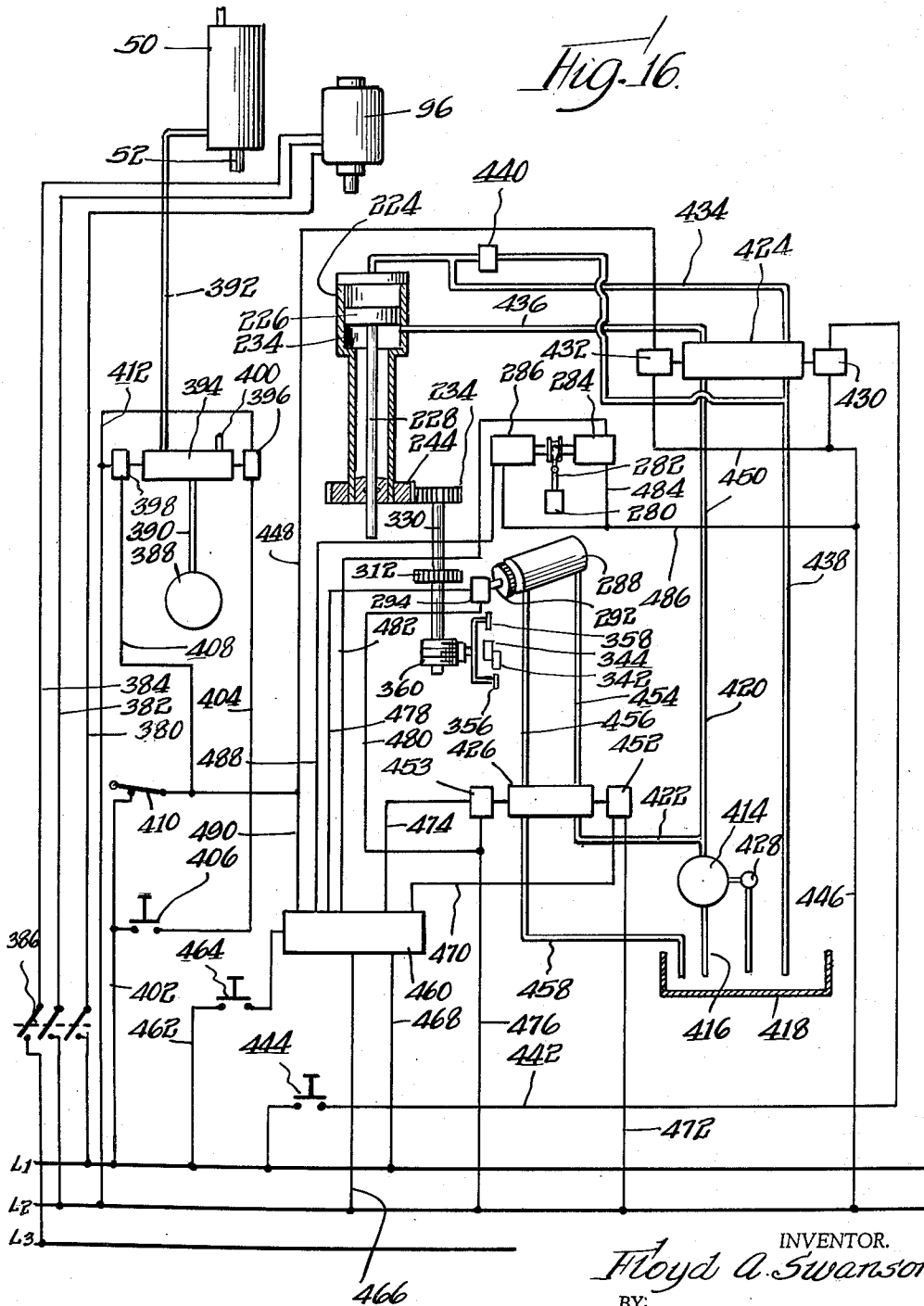
F. A. SWANSON

3,013,363

HONING APPARATUS

Filed Oct. 10, 1958

6 Sheets-Sheet 6



INVENTOR.
Floyd A. Swanson
BY: *Olson & Trefler*
attys

1

3,013,363

HONING APPARATUS

Floyd A. Swanson, Rockford, Ill., assignor, by mesne assignments, to National Automatic Tool Company, Inc., Richmond, Ind., a corporation of Indiana
Filed Oct. 10, 1958, Ser. No. 766,592
9 Claims. (Cl. 51—34)

The present invention relates to a novel apparatus for machining or working the surface of an aperture in a workpiece, and more particularly to a novel honing machine.

Honing machines have heretofore been suggested which utilizes a honing tool including a radially expandable set of honing stones which is adapted to be reciprocated and rotated within a workpiece. Certain of the heretofore proposed machines have not been capable of maintaining a high degree of control over the manner in which the honing stones are fed or radially expanded so that the finished workpiece bore or aperture surfaces may be unduly tapered or out of round. In addition, certain of the heretofore proposed honing machines have been relatively complicated and expensive to produce and maintain.

It is an important object of the present invention to provide a novel honing machine which is of relatively simple, rugged and economical construction and which is adapted to control the expansion or feeding of a honing tool in a manner which enables workpieces to be finished more accurately and rapidly.

A more specific object of the present invention is to provide a honing machine which includes novel mechanical means for reciprocating rotating and radially feeding a honing tool.

A more specific object of the present invention is to provide a novel honing machine of the type mentioned in the preceding paragraph which is adapted to be adjusted for accommodating workpieces of different sizes.

Still another specific object of the present invention is to provide a novel honing machine which is constructed so as to accomplish radial feeding or expanding of a honing tool in a precise and controlled manner and so as to limit the pressure with which the honing tool is engaged against a workpiece so as to promote accurate finishing of a workpiece and to reduce any possibility of injury to the workpiece or the honing tool.

Other objects and advantages of the present invention will become apparent from the following description and the accompanying drawings wherein:

FIG. 1 is a side elevational view showing an apparatus incorporating features of the present invention;

FIG. 2 is a front elevational view of the apparatus;

FIG. 3 is an enlarged fragmentary front elevational view which is partially broken away in order to show certain features more in detail;

FIG. 4 is a fragmentary side elevational view of that portion of the apparatus shown in FIG. 3;

FIG. 5 is a fragmentary partial sectional view taken generally along line 5—5 in FIG. 4;

FIG. 6 is an enlarged fragmentary sectional view taken generally along line 6—6 in FIG. 5;

FIG. 7 is a fragmentary sectional view taken along line 7—7 in FIG. 6;

FIG. 8 is an enlarged fragmentary elevational view taken generally along line 8—8 in FIG. 3 and showing a unit of the apparatus which functions for causing reciprocation of a honing tool;

FIG. 9 is a fragmentary sectional view taken generally along line 9—9 in FIG. 8;

FIG. 10 is a fragmentary sectional view taken generally along line 10—10 in FIG. 8;

2

FIG. 11 is a fragmentary sectional view taken generally along line 11—11 in FIG. 9;

FIG. 12 is a fragmentary elevational view taken generally along line 12—12 in FIG. 3 and showing a portion of a subassembly of the apparatus whereby radial feeding or expansion of a honing tool may be accomplished;

FIG. 13 is a fragmentary elevational view of the unit shown in FIG. 12 as seen from the left hand end thereof;

FIG. 14 is a fragmentary elevational view of the unit shown in FIG. 12 as seen from the right hand end thereof;

FIG. 15 is a fragmentary sectional view taken generally along line 15—15 in FIG. 12; and

FIG. 16 is a diagrammatic view showing actuating and control circuits for the apparatus of the present invention.

Referring now more specifically to the drawings wherein like parts are designated by the same numerals throughout the various figures, an apparatus 20 incorporating features of the present invention is shown generally in FIGS. 1 and 2. The apparatus 20 is provided with a frame structure 22 extending upwardly from a base 24 and having vertical guideways 26 and 28 upon which a head structure 30 is slidably supported. As shown in FIGS. 1—5, the head structure 30 includes an outer housing or frame 32 having surface portions 34 and 36 mating with the guideways 26 and 28 and flanges 38 and 40 extending around the guideways. Guidebars 42 and 44 are secured to the flanges 38 and 40 and project behind the guideways for retaining the head structure in association with the guideways.

In order to raise and lower the head structure 30 during placement of a workpiece 46 on or removal of the workpiece from a fixture 48 in the manner described below, a fluid motor 50 is mounted on the main frame 22. The fluid motor comprises a cylinder having a piston reciprocable therein and connected to a rod 52 which in turn is connected with a lug 54 fixed to the head frame 32. Adjustable stop means is provided for positively locating the lowermost position of the head structure 30. As shown in FIG. 1, this stop means may include a screw member 56 supported by a boss 58 mounted on the main frame 22 and adjustably secured in position by jam nuts 60 and 62.

The apparatus of the present invention is adapted to utilize a honing tool 64 which is shown generally in FIGS. 1 and 2. The honing tool forms no part of the present invention and may be of known construction so that it need not be described in detail. It suffices to state that the honing tool is of a type adapted to be reciprocated and rotated within a bore in a workpiece and having a set of circumferentially spaced honing stones which are adapted to be radially fed or expanded in response to axial movement of an actuating rod, not shown. As will be understood, the structure of the honing tool is such that when the actuating rod is axially moved downwardly or in one direction the honing stones will be radially expanded or fed and when the actuating rod is moved in the opposite direction or upwardly the honing stones will be radially collapsed toward their original positions.

The apparatus is provided with a main spindle structure 66 for supporting and actuating the honing tool, which spindle structure is shown generally in FIGS. 1—5 and more in detail in FIGS. 6 and 7. The spindle structure 66 includes a spindle 68 having a socket portion 70 at an end thereof for detachable connection to the honing tool. A bore 72 extends axially completely through the spindle 68 for accommodating an actuating rod 74 which is operated in the manner described in de-

tail below for controlling the radial feeding or expansion of the honing tool.

In order to rotate the spindle and thus the honing tool, the spindle 68 is mounted within a sleeve 76 which in turn is rotatably supported and retained against axial displacement by upper and lower bearing assemblies 78 and 80. These bearing assemblies are mounted in fixed portions of the head frame structure 32. A gear 82 is fixed on an upper end of the sleeve 76 by a nut 84 or any other suitable means, which gear is driven by a pinion 86 fixed on a main drive shaft 88. The drive shaft is rotatably supported by bearing assemblies 90, 92 and 94 mounted on the head frame structure 32, and the shaft is driven by suitable means described below.

The drive means of the apparatus comprises an electric motor 96 mounted on a bracket 98 extending upwardly from the head structure 30 as shown in FIGS. 1 and 2. The motor 96 has an output shaft 100 coupled with an input shaft 102 of a gear train which is shown in simplified form in FIG. 5. A pinion 104 is fixed on the shaft 102 and meshes with a gear 106 secured to another shaft 108. Another gear 110 fixed on the shaft 108 meshes with and drives a gear 112 which is secured to a rotatably mounted shaft 114 having still another gear 116 fixed thereon. The gear 116 meshes with an idler gear 118 mounted on a shaft 120. The gear 118 meshes with and drives a gear 122 fixed on the main drive shaft 88. It will be appreciated that the gears in the drive means may be replaced by other gears of various sizes so that the speed at which the spindle is ultimately rotated may be varied as desired.

As indicated above, the spindle structure 66 is adapted to be actuated so as to reciprocate the honing tool. More specifically, the spindle 68 is adapted to reciprocate within the sleeve 76. The spindle 68 is provided with axially extending splines 124 cooperable with complementary axially extending splines 126 at the interior of the sleeve 76 for providing a driving connection between the sleeve and the spindle 68 while enabling the spindle to reciprocate relative to the sleeve.

In accordance with a feature of the present invention, mechanical means is provided for reciprocating the spindle 68 relative to the head frame structure 32 as distinguished from honing machines heretofore in general use utilizing pneumatic or fluid means for reciprocating an entire head structure. More specifically, a unit 128 for reciprocating the spindle 68 is shown in whole or in part in FIGS. 4, 6, 8, 9, 10 and 11. The unit 128 is provided with a support or frame structure 130 which is mounted within the head frame structure 32. A shaft 132 is rotatably supported within a bore extending through the frame structure 130 by bearing assemblies 134 and 136. A worm gear 138 is fixed on one end of the shaft 132, which worm gear meshes with and is driven by a worm 140 fixed on the main drive shaft 88 as shown in FIGS. 6, 8 and 10. A pinion 142 is fixed on the opposite end of the shaft 132 and drives a gear 144 which is keyed or otherwise fixed to a shaft 146 rotatably supported by bearing assemblies 148 and 150. An eccentric pin 152 is adjustably connected with and rotated by the shaft 146 in the manner described fully below for actuating a connecting link 154 which in turn actuates a lever 156. As shown in FIGS. 8-10, the lever 156 has an intermediate portion connected to the link 154 by a pin 158 and one end portion connected to a fixed pivot pin 160 which is supported by lugs 162 and 164 extending upwardly from the support or frame structure 130. An opposite end of the lever 156 is bifurcated so as to provide arms 166 and 168 adapted loosely to embrace the spindle 68 as shown best in FIGS. 6 and 10. Stub shafts or pivot pins 170 and 172 project laterally outwardly from the arms 166 and 168 respectively, which pins are operatively interconnected with the spindle 68 in the manner described below so that when the lever 156 is oscillated in response to rotation of the eccentric pin 152, the spindle 68 is reciprocated.

It will be appreciated that it may be desirable to change the length of the reciprocable motion of the honing tool for workpieces having different thicknesses. Such adjustment of the reciprocable movement of the honing tool may be accomplished in the apparatus of the present invention by changing the position of the eccentric pin 152 which controls the length of the oscillating movement of the lever 156. More specifically, the eccentric pin 152 is formed integrally with a shaft 174 which extends through a bore 176 formed through the shaft 146. The pin 152 is eccentrically disposed with respect to the shaft 174, and the bore 176 and thus the shaft 174 are eccentrically disposed in the shaft 146. As a result, the position of the pin 152 with respect to the shaft 146 may be adjusted between substantial axial alignment with the shaft 146 and maximum eccentricity, the latter position being shown in FIG. 11. This adjustment is accomplished by turning the shaft 174 relatively to the shaft 146. The shaft 174 may be locked in any desired adjusted position by means of a plate member 180 which is keyed or otherwise secured to the shaft 174 and which has ribs or splines 182 at one axial face thereof cooperable with complementary ribs or splines on an axially facing end of a second clutch disc or plate member 184 which is fixed with respect to the gear 144 by means of a pin 186. A nut member 188 is applied to a threaded end of the shaft 174 for releasably clamping the clutch plate 180 against the plate member 184. It will be appreciated that the relatively small amount of eccentricity between the pin 152 and the shaft 146 will result in a relatively large reciprocable movement of the spindle 68 and thus the honing tool since the eccentric pin 152 is operatively interconnected with a mid-portion of the spindle actuating lever 156 through the link 154 so that the motion of the eccentric pin is effectively doubled at the free end of the actuating lever 156.

The pins 170 and 172 and thus the oscillating lever 156 are operatively interconnected with the spindle 68 in the manner shown in FIG. 6. More specifically, an axially short sleeve 190 loosely surrounds the upper end of the spindle 68 and provides seats receiving upper and lower combined radial and thrust bearing assemblies 192 and 194 which are disposed between the sleeve and the spindle 68. A washer 196 is disposed beneath the bearing assembly 194 and is located by a shoulder 198 on the spindle 68 for preventing axial displacement of the sleeve 190 and the associated bearing assemblies downwardly. A nut member 200 is threaded onto the upper end of the spindle 68 for retaining the bearing assemblies and sleeve 190 against upward axial displacement relative to the spindle. Axially aligned stub shafts or pin elements 202 and 204 are formed integrally with or secured to the sleeve 190 and extend in opposite directions therefrom, which pin elements are respectively interconnected with the pins 170 and 172 by links 206 and 208. Thus the oscillating movement of the lever 156 will be transferred through the links and the sleeve 190 to the spindle. Preferably, a compression spring 210 is provided between the washer 196 and a seat 212 formed in the sleeve 76 for cushioning the reciprocating movement of the spindle.

As indicated above, the apparatus is provided with means for controlling axial displacement of the rod 74 extending through the spindle 68 and thereby controlling the radial expansion and contraction of the honing tool. This expansion or feed controlling means is generally designated by the numeral 220 and is shown best in FIGS. 3-7 and 12-15. The feed control means comprises a fluid cylinder 224 shown best in FIGS. 6 and 7 and having a piston 226 reciprocally disposed therein and connected with a rod 228. The rod 228 is connected with the rod 74 for axial movement in unison therewith, and this connection is accomplished by means of a suitable rotary coupling 230 so that the rod 74 may rotate with the spindle 68 and relative to the rod 228. The piston 226 is actuated by fluid or hydraulic liquid

entering an inlet port 232 so as to advance or downwardly shift the rod 228 and thus the actuating rod 74 for causing radial expansion or feeding of the honing tool. Such movement of the piston is limited by a rigid abutment or stop provided by an internal shoulder 234 in the fluid cylinder. Reverse or upward movement of the piston which permits radial collapsing of the honing tool is accomplished by means of a compression spring 236 disposed between the piston and an internal shoulder 238 provided adjacent the lower end of the cylinder.

The hydraulic or fluid cylinder 224 is connected for reciprocable movement in unison with the spindle 68 so that such movement has no effect upon the operation of the feed control rod 74. In addition, the cylinder 224 is adapted to be bodily axially shifted relative to the spindle 68 in a precisely controlled manner so as to accomplish axial movement of the control rod 74 in addition to the movement of this rod which results from the operation of the piston 226. More specifically, the construction is such that the piston 226 is operated between upper and lower positive limits of its travel either to expand or contract the honing tool relatively rapidly at the beginning and end of a honing operation while the cylinder 224 is bodily shifted to accomplish relatively slow expansion or feeding movement of the honing tool.

In order to accomplish the results mentioned in the preceding paragraph, the cylinder 224 has an elongated reduced diameter lower end portion 240 which is externally threaded and which receives a complementary threaded nut like member or sleeve 242. A gear 244 is keyed or otherwise fixed on the nut member so that the nut member may be rotated and suitable means is provided for retaining the cylinder against rotation. This means includes a pair of vertical guide rods 246 and 248 which are suitably fixed within the head frame structure 32. Slide bearings 250 and 252 are disposed on the rods 246 and 248 and secured to or formed integrally with an upper end portion of the cylinder 224. Similar slide bearings 254 and 256 are secured to or formed integrally with the support ring 258 encircling the nut member and carrying a pair of bearing assemblies 260 and 262, which serve to rotatably support the nut member. A lower end of the support ring 258 is welded or otherwise interconnected with a rigid sleeve 264 which extends downwardly around the rotary coupling 230 and has its lower end welded or otherwise fixed to the sleeve 190. Thus the support ring 258 and the nut member 242 are fixed against axial displacement relative to the spindle 68 so that upon rotation of the nut member, the cylinder 224 will be axially displaced relative to the spindle.

In order to drive the gear 244 and thus the nut member 242 for causing radial expansion or feeding movement of the honing tool during a honing operation, the control means 220 is provided with a drive mechanism 266 which is shown best in FIGS. 6 and 12-15. This unit includes a support or frame member 268 suitably mounted within the head frame structure 32. A shaft 270 is rotatably supported by the frame member 268 and has fixed thereon a worm wheel 272 which meshes with and is driven by a worm 274 fixed on the main drive shaft 88. A second shaft 276 is rotatably supported on the frame member 268 in axial alignment with the shaft 270 and these shafts respectively carry complementary clutch members 278 and 280 so that the shafts may be selectively connected and disconnected. A pivotally supported lever 282 is provided for actuating the clutch member 280 into and out of engagement with the clutch member 278, and electric solenoids 284 and 286 are provided respectively for actuating the clutch lever 282 to connect and disconnect the clutch members 278 and 280. The clutch members are normally engaged with each other during a honing operation so that the nut member 242 is rotated in response to rotation of the main drive shaft 88. The gearing arrangement is such that this rotation of the nut

member is relatively slow and there are instances when it is desirable to rotate the nut member relatively rapidly. During these instances the clutch members are disengaged and the drive mechanism is provided with additional means described below for accomplishing the desired relatively rapid rotation of the nut member.

In order to rotate the nut member relatively rapidly as mentioned above, the drive unit 266 is provided with a reversible rotary fluid motor 288 mounted on the frame member 268 and having an output shaft 290 to which is fixed a gear 292. An electrically operated brake unit 294 is also connected with the motor shaft 290 for preventing overrun of the motor and for releasably locking the motor after it has served to rotate the nut member 244 to accomplish the desired rapid adjustment of the fluid cylinder 224.

The gear 292 meshes with a gear 296 formed integrally with or rigidly connected to another gear 298 and fixed on a shaft 300 which is rotatably mounted in the support frame member 262. A gear 302 is fixed on the shaft 300 at an end thereof opposite from the gears 296 and 298, and the gear 302 meshes with and is adapted to be driven by a gear 304 which is fixed on the shaft 276. Thus it is seen that the gear 298 can selectively be driven in response to rotation of the fluid motor 288 or in response to rotation of the main drive shaft 88. The gear 298 is in turn adapted to mesh with and drive a gear 306 fixed on a shaft 308 which also carries a worm 310.

The worm 310 meshes with and drives a worm wheel 312 which is keyed or otherwise fixed on a shaft 314 which is rotatably supported by bearing units 316 and 318 disposed in seats formed in flanges 320 and 322 of the support frame member 268. A flange 324 on the shaft 314 limits axial downward movement of the shaft, and an oppositely facing nut member 326 provided on a threaded lower end portion 328 of the shaft prevents axial movement of the shaft in an opposite or upward direction. An upper end portion 330 of the shaft 314 is provided with axially extending splines which provide a driving connection between the shaft and a bushing 332 which is axially slidably disposed on the shaft as shown in FIG. 6. The bushing carries fixed thereon a gear 334 which meshes with and drives the gear 244. It will be noted that the bushing 332 is rotatably supported by bearing units 336 and 338 mounted on a lateral extension 340 of the support ring 258, and the bushing is provided with a lower end flange which cooperates with the gear 334 in preventing axial displacement of the bushing relative to the support 340. Thus the bushing 332 and the gear 334 mounted thereon will reciprocate in unison with the spindle structure 66.

The unit 266 has incorporated therewith means for providing an indication of the condition of wear of the honing stones to an operator. As shown in FIGS. 12, 13 and 15, this means comprises a pair of switches 342 and 344 which are respectively electrically connected for energizing signal lights or other suitable means, not shown, for providing an indication that the honing tool is provided with new stones and is properly adjusted for beginning an initial honing operation and for providing an indication that the honing stones are worn out and need replacement. The switches are fixed on a mounting plate 346 which in turn is secured to the frame or support member 268 and partially covers an elongated slot 348 in the frame member 268. A slide member 350 is retained within the slot by the mounting plate 346 and includes laterally extending opposite end flanges 352 and 354. These flanges respectively carry fixed but adjustable switch actuating elements or screws 356 and 358. The slide member 350 is connected to the block 360 threaded onto the lower end portion 328 of the shaft 314, and this connection is obtained by means of a screw 362 which projects through an elongated opening 364 in the support member 268. With this structure, the apparatus may be rapidly set up for an initial honing operation after the installation

of a new set of honing stones by operating the fluid motor 288 so as to rotate the shaft 314 until the block 360 has been raised to the position shown in FIG. 13 so that the element 356 engages and actuates the switch 342. Upon subsequent operation of the apparatus which will be described in detail below, the shaft 314 is rotated so that the block 360 and thus the slide 350 are progressively moved downwardly. After each honing operation is accomplished the apparatus will be re-set in the manner described below, but as the honing stones become worn, the block 360 and the slide 350 will reach progressively lower positions at the end of each honing operation until finally the element 358 engages and actuates the switch 344 to provide an indication that the honing stones need replacement.

FIG. 16 shows simplified fluid and electrical circuits which may be provided for operating the apparatus in the manner to be described. More specifically, the electric motor 96 is connected with power lines L1, L2 and L3 by wires 380, 382 and 384 in which a suitable switch 386 is connected. The air cylinder 50 is connected with any suitable source 388 of air under pressure by conduits 390 and 392 which in turn are connected with each other through a two position valve 394. Solenoids 396 and 398 are connected with the valve spindle so that when, for example, the solenoid 396 is energized the valve will be shifted so as to connect the conduit 392 with a vent port 400 and when the solenoid 398 is energized the valve will be shifted so as to connect the conduit 392 and thus the lower end of the cylinder 50 with the source of air under pressure. Thus the solenoid 396 is energized in order to permit lowering of the piston rod 52 and the head means 30 of the apparatus, and the solenoid 398 is energized when it is desired to raise the head means 30. In order to control the solenoids in the desired manner, the solenoid 396 is connected with the power line L1 through wires 402 and 404 having a momentary contact push button switch 406 connected therein and the solenoid 398 is connected with the power line L1 through the wire 402 and a branch wire 408 having a limit switch 410 connected therein and actuated in the manner described below. The solenoids 396 and 398 are also connected with the line L2 by a wire 412 and suitable branch wires in order to complete the circuit. With this arrangement, it will be appreciated that when the switch 406 is closed the cylinder 50 will be operated so as to lower the head structure 30 and when the limit switch 410 is closed the cylinder 50 will be operated so as to raise the head structure.

In order to actuate the piston 226 in the cylinder 224 and also the rotary fluid motor 288, a continuously driven hydraulic pump 414 is provided for supplying fluid under pressure. The pump has an inlet conduit 416 communicating with a suitable reservoir 418 and an outlet connected by conduits 420 and 422 with inlet ports of control valves 424 and 426 which are respectively associated with the cylinder 224 and the fluid motor 288. A relief valve 428 is also connected with the pump for returning fluid to the reservoir in the event neither the cylinder 224 nor the fluid motor 288 require additional fluid.

The valve 424 is a two position valve and is adapted to be actuated by solenoids 430 and 432. The valve is connected with opposite ends of the cylinder 224 by conduits 434 and 436, and a drain conduit 438 extends between an outlet port of the valve and the reservoir 418. The construction of the valve is such that when the solenoid 430 is energized the valve is shifted to and remains in a condition wherein the hydraulic power line 420 is connected with the conduit 434 so as to direct hydraulic fluid under pressure into the upper end of the cylinder 224 and force the piston 226 downwardly until it positively engages the stop or shoulder 234. At the same time the drain conduit 438 is connected with the conduit 436 which communicates with the lower ends of the cylinder. The construction of the valve 424 is also such that

when the solenoid 432 is energized, the valve is shifted to and remains in a condition wherein the hydraulic power line 420 is connected with the lower end of the cylinder 224 through the conduit 436 and the upper end of the cylinder is connected with the drain line so that the piston 226 will be raised. It is to be noted that a pressure relief valve 440 is connected in the conduit 434 adjacent the cylinder 224. This relief valve prevents the build up of undue pressures during a honing operation since the pressure of the honing tool against the workpiece will be transmitted to the hydraulic fluid in the upper end of cylinder 224 and when this pressure reaches a predetermined limit the relief valve 440 will open to permit the honing tool to retract from the workpiece sufficiently to relieve the undue pressure.

The solenoid 430 is connected with the power line L1 by a wire 442 having a momentary contact switch 444 therein, and another terminal of the solenoid 430 is connected with the line L2 by a wire 446. The solenoid 432 has one terminal connected with the limit switch 410 by a wire 448 and another terminal connected with the line L2 by the wire 446 and a suitable branch wire 450. With this arrangement, the switch 444 is manually closed at the start of the honing operation so as to cause the piston 226 to be lowered against the stop 234, and at the end of the honing operation the solenoid 432 is energized when the limit switch 410 is closed so as to cause the piston 226 to be raised whereby substantially instantly to retract the honing stones from the workpiece.

The valve 426 is a two position valve similar to the above mentioned valve 424 and is constructed so that a valve element thereof may be selectively shifted by solenoids 452 and 453 for directing hydraulic fluid to the motor 288 in the manner described below. More specifically, the reversible fluid motor 288 has ports connected with a pair of ports of the valve 426 by conduits 454 and 456, and the valve 426 has another port connected with a reservoir by a drain line 458. The construction is such that when the solenoid 452 is energized the valve 426 will be shifted so as to connect the conduits 454 and 456 with the power and drain conduits 422 and 458 respectively so as to cause forward rotation of the motor 288 and thus downward feed movement of the cylinder 224. When the solenoid 453 is energized the conduits 454 and 456 are respectively connected with the drain line 458 and the power line 422 so as to cause reverse rotation of the motor.

The solenoids 452 and 453 are connected with and controlled by a timer 460. More specifically, the timer has one terminal of a control circuit connected with the power line L1 by a wire 462 having a switch 464 connected therein, and another terminal of the control circuit is connected with the line L2 by a wire 466. A power circuit of the timer has one terminal connected with the power line L1 by a wire 468 and another terminal connected with the solenoid 452 by a wire 470. The solenoid 452 is also connected with the line L2 by a wire 472 in order to complete this circuit. The solenoid 453 is connected with another terminal of the timer by a wire 474 and also with the line L2 by a wire 476. The timer also serves to control the operation of the brake 294 associated with the motor 288 and of the clutch actuating solenoids 284 and 286. Thus the solenoid of the brake 294 has one terminal connected with the timer by a wire 478 and another terminal connected with the line L2 through the wire 476 and a branch wire 480. The solenoid 284 is connected with the wire 470 by a branch wire 482 so that the solenoid 284 is operated to disengage the clutch member 280 from the clutch member 278 when the solenoid 452 is energized so as to cause the fluid motor 288 to rotate in the forward direction. The circuit of the solenoid 284 is completed by wires 484 and 486 which are connected to the line L2 by the wire 446. The solenoid 286 is connected with the timer by a wire 488 and also with the circuit completing wire 486. It will be noted that a con-

trol circuit of the timer is connected with the limit switch 410 by a wire 490, which control circuit is adapted to operate the solenoid 453 and the brake 294 so as to cause reverse rotation of the motor 288 in the manner described below.

A résumé of the manner in which the apparatus described above may be operated is as follows. Starting with the piston 52 and thus the head structure 30 in a raised position, a workpiece is properly positioned for engagement by the honing tool. Then the switches 386, 444 and 464 are closed so that the electric motor 96 is energized, the solenoid 430 is energized so as to cause the piston 226 to be shifted downwardly against the stop 234 and the timer is actuated so as to energize the solenoid 452 and the brake 294 for causing forward rotation of the fluid motor 288 and so as to energize the clutch operating solenoid 284 in a manner which insures disengagement of the clutch. It will be appreciated that as the piston 226 moves downwardly against the stop 234, the honing tool will be rapidly expanded a predetermined amount which preferably is insufficient to bring the honing stones into engagement with the work. Then the rotation of the fluid motor 288 in the forward direction bodily feeds the cylinder 224 so as further to advance or feed the honing stones relatively rapidly. The timer 460 is constructed so that the substantially constant speed motor 288 is stopped after a predetermined interval of time during which the honing stones have been fed or expanded a predetermined amount and substantially into engagement with the work. At the same time as the fluid motor 288 is stopped, the clutch operating solenoid 284 is deenergized and the solenoid 286 is energized so as to engage the clutch to cause the honing stone feeding means to be relatively slowly driven from the main drive shaft 88 in the manner described above. It is understood, of course, that at the same time the honing tool spindle is being vertically reciprocated in the manner also described above.

When the honing operation has been completed, a size ring on the honing tool enters the workpiece aperture so as to permit a dog 492, see FIG. 2, to engage and close the limit switch 410. When the limit switch is closed, the solenoid 432 is energized so as to cause the piston 226 to be raised and immediate disengagement of the honing stones from the workpiece. In addition, the solenoid 398 is energized so as to actuate the piston 52 and raise the head structure 30 and a control circuit of the timer is energized so as to actuate the solenoids 284 and 453 and the brake 294 to disengage the clutch 280 and the brake 294 and to cause reverse rotation of the fluid motor 288.

As will be appreciated, the honing stones will wear during each honing operation. In order to compensate for such wear and thereby to reduce the time required to feed the honing stones into engagement with successive workpieces, the timer 460 is constructed so that the time interval during which the fluid motor 288 is driven in a reverse direction in order to retract the honing stones is sufficient to retract the honing stones a radial distance slightly less than the overall radial feeding movement of the stones accomplished by the forward rotation of the fluid motor 288 and the mechanical drive during the honing operation. As a result, the block 360 on the shaft 330 will be progressively lowered after each honing operation an amount which corresponds to the wear of the honing stones so that the switch 344 is actuated when the stones are worn sufficiently to require replacement. As will be understood, the switch 344 as well as the switch 342 may be connected in suitable circuits including indicator lights, not shown, so that an operator may readily observe the condition of the stones.

While the preferred embodiment of the present invention has been shown and described herein, it is obvious that many structural details may be changed without

departing from the spirit and scope of the appended claims.

The invention is claimed as follows:

1. An apparatus for machining a workpiece comprising a support structure, tool spindle means rotatably and reciprocally mounted on said support structure, said spindle means including tool feeding means shiftable relative to portions of said spindle means, means on said support structure for rotating and simultaneously reciprocating said spindle means relative to the support structure during a workpiece machining operation, and means on said support structure for rapidly advancing said feeding means to position a tool for engagement with a workpiece and for subsequently relatively slowly advancing said feeding means during engagement of a tool with the workpiece.

2. An apparatus for machining a workpiece comprising a support structure mounted for movement to and from advanced and retracted positions, tool spindle means rotatably and reciprocally mounted on said support structure and including tool feeding means shiftable relative to portions of said spindle means, means on said support structure for rotating and simultaneously reciprocating said spindle means during a workpiece machining operation, means for advancing said tool feeding means for accomplishing machining of a workpiece, and means for retracting said tool feeding means at the end of a workpiece machining operation less than it was advanced during the workpiece machining operation so as to compensate for tool wear.

3. An apparatus for machining a workpiece comprising a support structure, a drive shaft rotatably mounted on said support structure, tool spindle means rotatably and reciprocally mounted on said support structure and including tool feeding means shiftable relative to portions of the spindle means, means on said support structure and connected to said drive shaft for rotating and simultaneously reciprocating said spindle means relative to the support structure during a workpiece machining operation, fluid pressure means for relatively rapidly actuating said feeding means to position a tool for engagement with a workpiece, and mechanical means connected to said drive shaft for positively actuating said feeding means in a predetermined manner during engagement of a tool with a workpiece.

4. An apparatus for machining a workpiece comprising a support structure, tool spindle means rotatably and reciprocally mounted on said support structure and including fluid operated tool feeding cylinder means having external thread means thereon and axially shiftable relative to portions of said spindle means, means on said support structure for rotating and simultaneously reciprocating said spindle means relative to the support structure, and means for shifting said cylinder means including internally threaded means cooperably engaging said threaded means on the cylinder means, a drive shaft parallel to said spindle means, and cooperable gear means between said drive shaft and said internally threaded means.

5. An apparatus, as defined in claim 4, which includes means for relatively rapidly driving said shaft for actuating said cylinder means to position a tool for engagement with a workpiece, and means for relatively slowly driving said shaft for causing relative slow feeding movement of a tool during engagement thereof with a workpiece.

6. An apparatus for machining a workpiece comprising a support structure, tool spindle means rotatably and reciprocally mounted on said support structure, means on said support structure for rotating said spindle means, and means on said support structure for reciprocating said spindle means relative to the support structure, said last mentioned means including eccentric drive means operatively interconnected with said spindle means, said

11

eccentric drive means comprising a rotatably supported shaft having an eccentric bore therethrough, a second shaft adjustably secured within said bore and including an end portion eccentric with respect to the remainder of said second shaft and operatively connectable with said spindle means, rotative adjustment of said second shaft relative to said first shaft varying the eccentricity of said end portion relative to said first shaft for varying the length of stroke of said spindle means.

7. An apparatus for machining a workpiece comprising a frame structure, a head structure adjustably mounted on said frame structure, rotatable tool spindle means, means on said head structure for rotating said spindle means, means for rotatably mounting said spindle means, means reciprocally mounting said spindle means mounting means on said head structure, means fixing said spindle means mounting means and said spindle means against relative axial movement, mechanical drive means on said head structure and including lever means connected with said spindle means mounting means for reciprocating said spindle means, tool feeding means on said spindle means and axially shiftable with respect to portions of said spindle means, said feeding means including an externally threaded section, internally threaded means rotatably disposed on said threaded section and retained against axial movement relative to said portions of said spindle means, and means for rotating said internally threaded means for actuating said feeding means.

8. An apparatus for machining a workpiece comprising a support structure, rotatable tool spindle means, means on said support structure for rotating said spindle means, means reciprocally mounted on said support structure and rotatably mounting said spindle means,

12

said last named means being fixed against axial movement relative to said spindle means, mechanical drive means including lever means connected with said spindle means mounting means for reciprocating said spindle means, tool feeding means on said spindle means and axially shiftable with respect to portions of said spindle means, said feeding means including an externally threaded section, internally threaded means rotatably disposed on said threaded section and retained against axial movement relative to said portions of said spindle means, and means for rotating said internally threaded means for actuating said feeding means, said last named means including a drive shaft and fluid motor means and mechanical means for selectively rotating said drive shaft relatively rapidly and relatively slowly.

9. An apparatus, as defined in claim 8, which includes clutch means for disconnecting said mechanical means from said drive shaft during operation of said fluid motor means.

References Cited in the file of this patent

UNITED STATES PATENTS

563,593	Hoenscheid	July 7, 1896
1,277,377	Carter	Sept. 3, 1918
2,229,318	Wallace	Jan. 21, 1941
2,251,607	Astrowski et al.	Aug. 5, 1941
2,301,111	Cuppers et al.	Nov. 3, 1942
2,563,301	Arms et al.	Aug. 7, 1951
2,795,089	Seborg	June 11, 1957

FOREIGN PATENTS

738,850	France	Oct. 18, 1932
888,659	Germany	Sept. 3, 1953