

Jan. 14, 1958

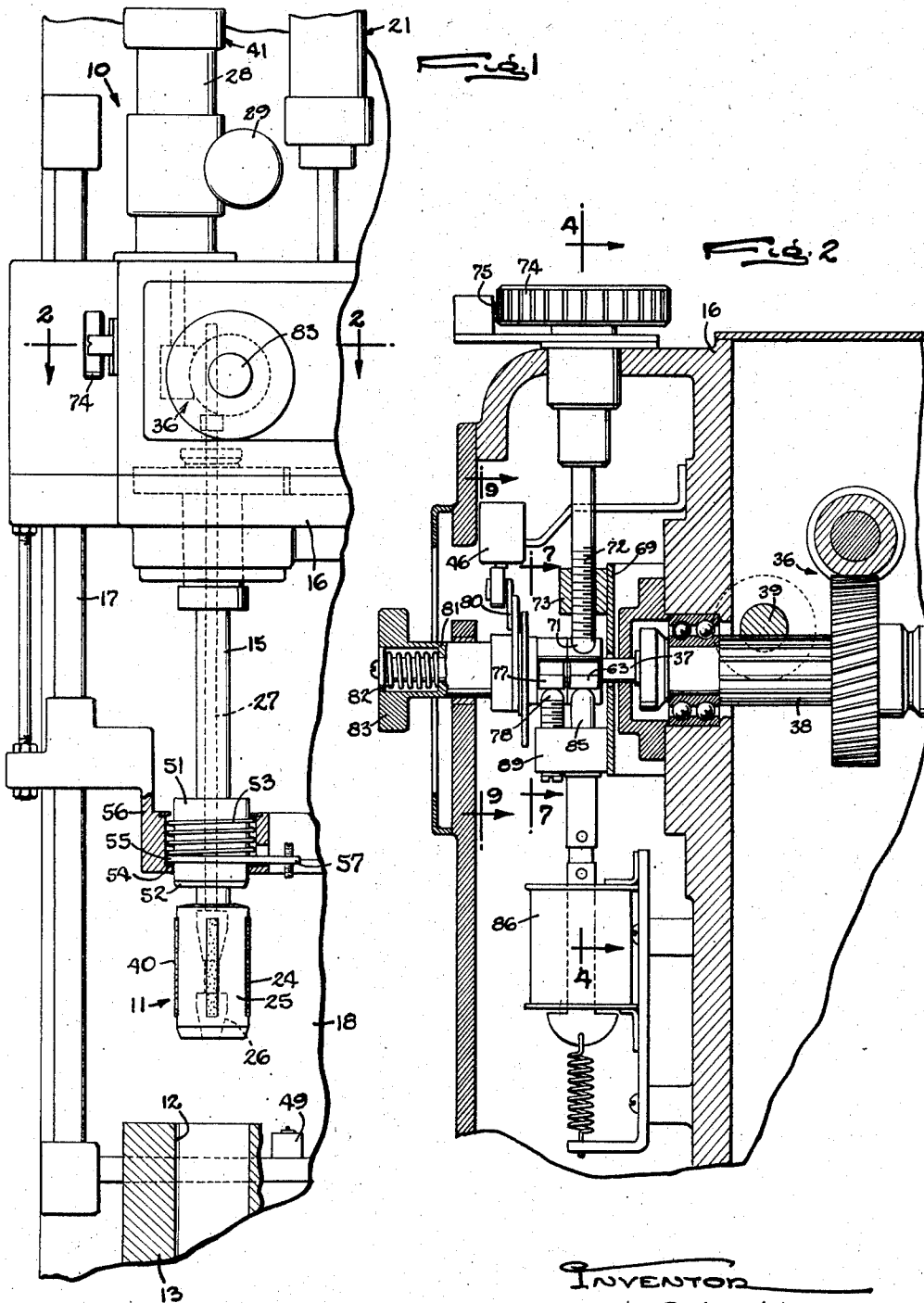
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2,819,566

HONE EXPANSION CONTROL MECHANISM

Filed Jan. 3, 1956

8 Sheets-Sheet 1



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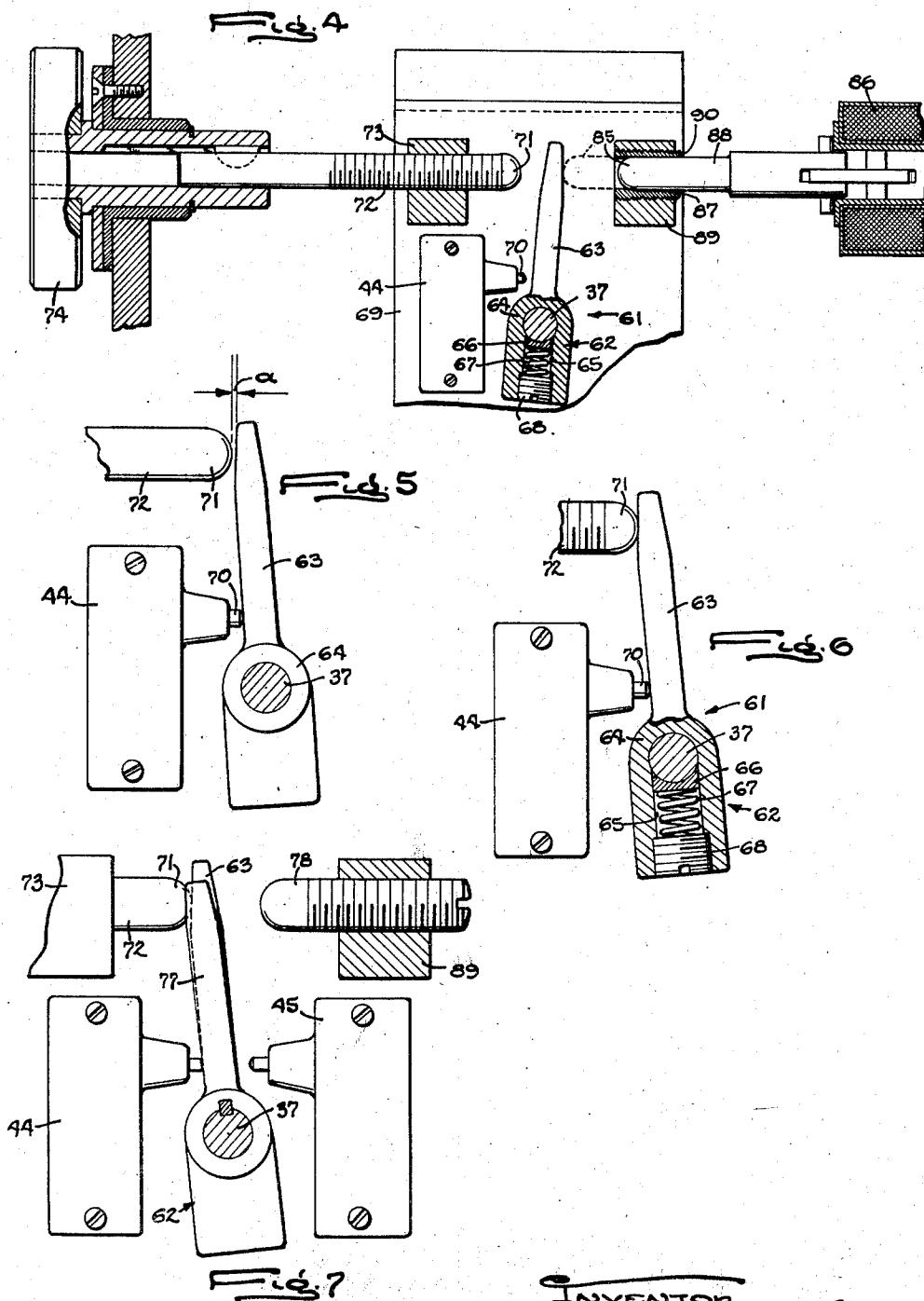
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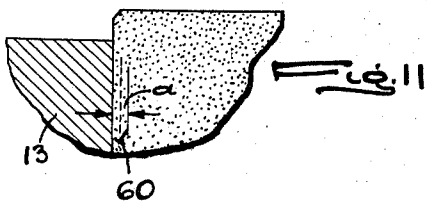
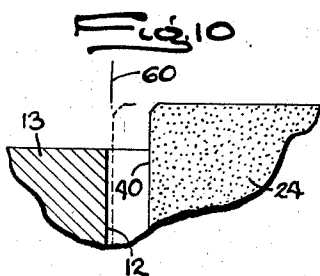
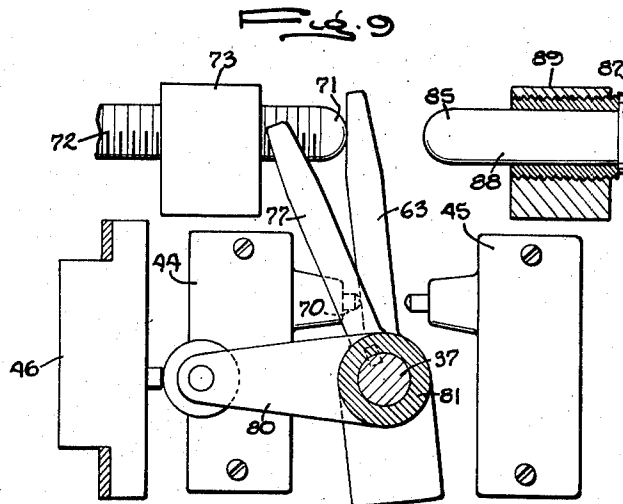
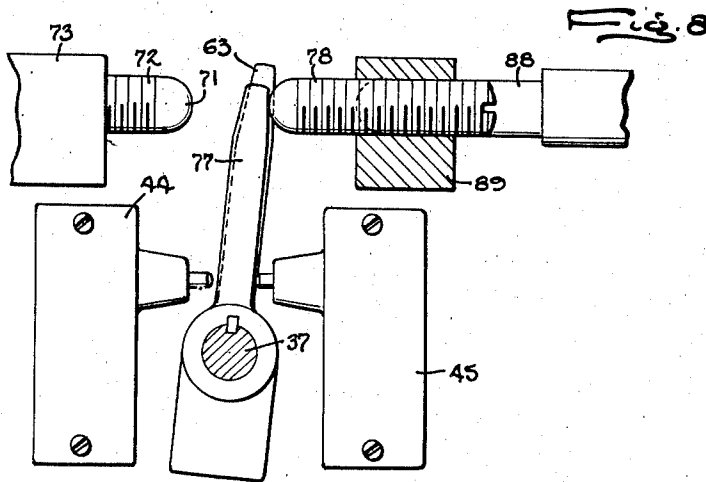
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HONE EXPANSION CONTROL MECHANISM

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8 Sheets-Sheet 4



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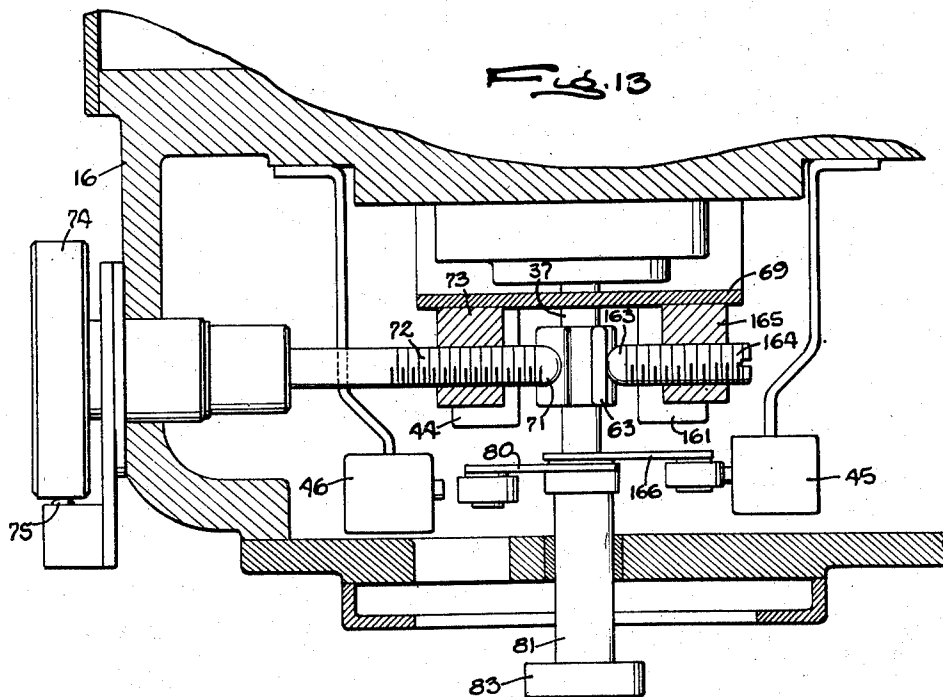
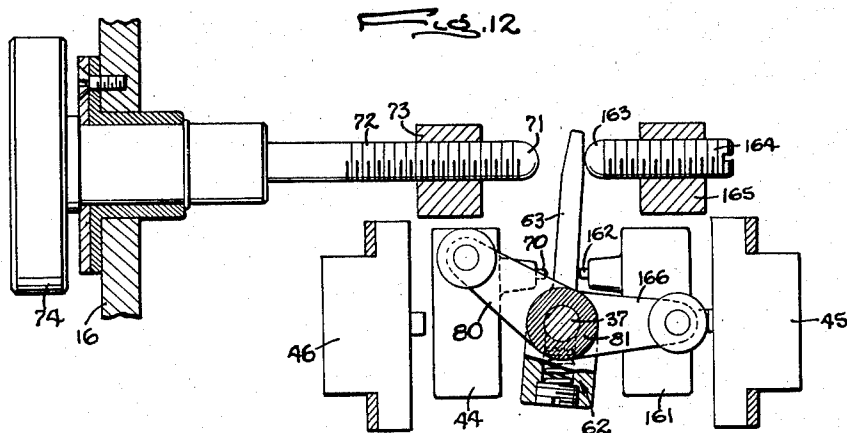
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HONE EXPANSION CONTROL MECHANISM

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8 Sheets-Sheet 5



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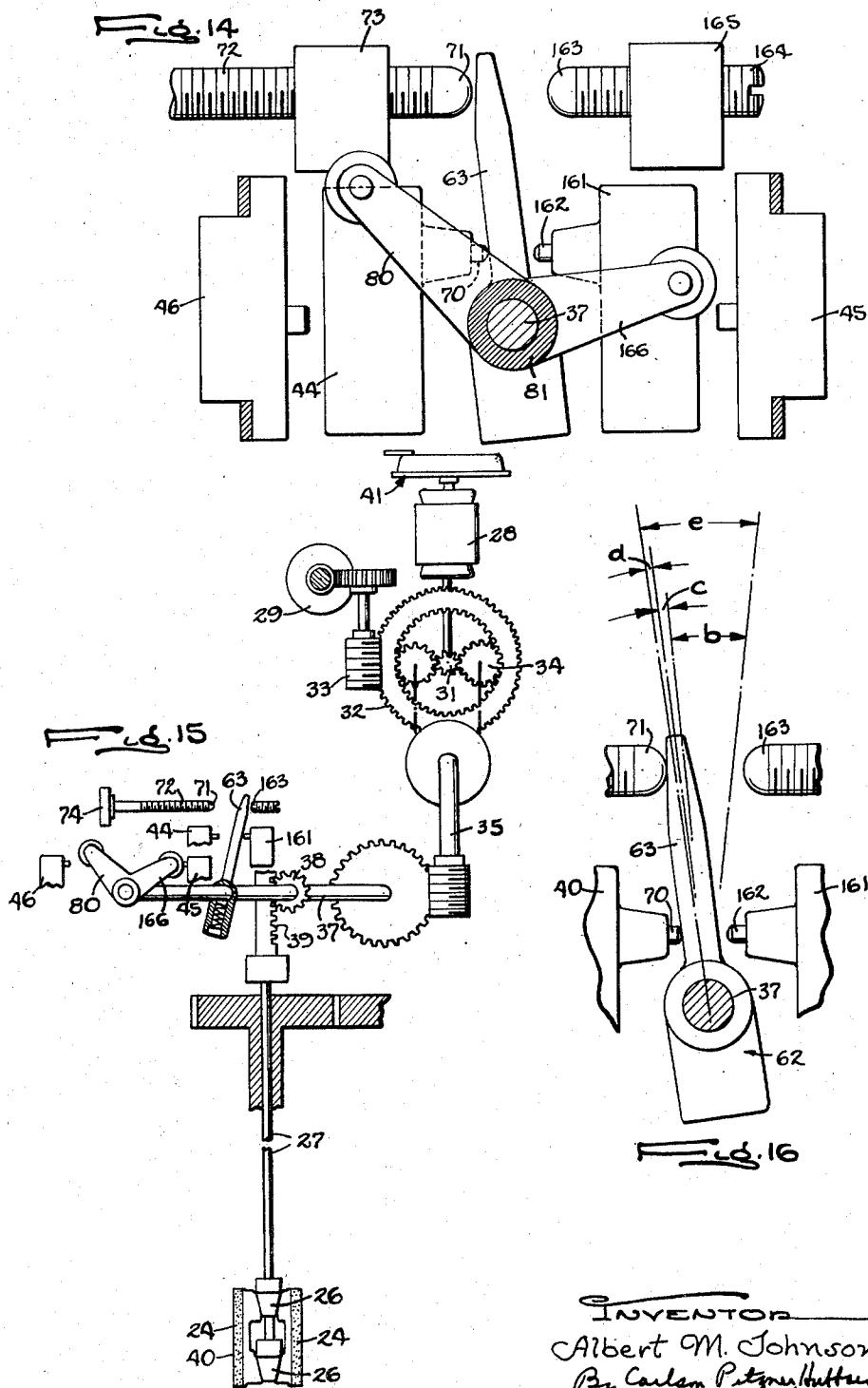
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HONE EXPANSION CONTROL MECHANISM

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8 Sheets-Sheet 6



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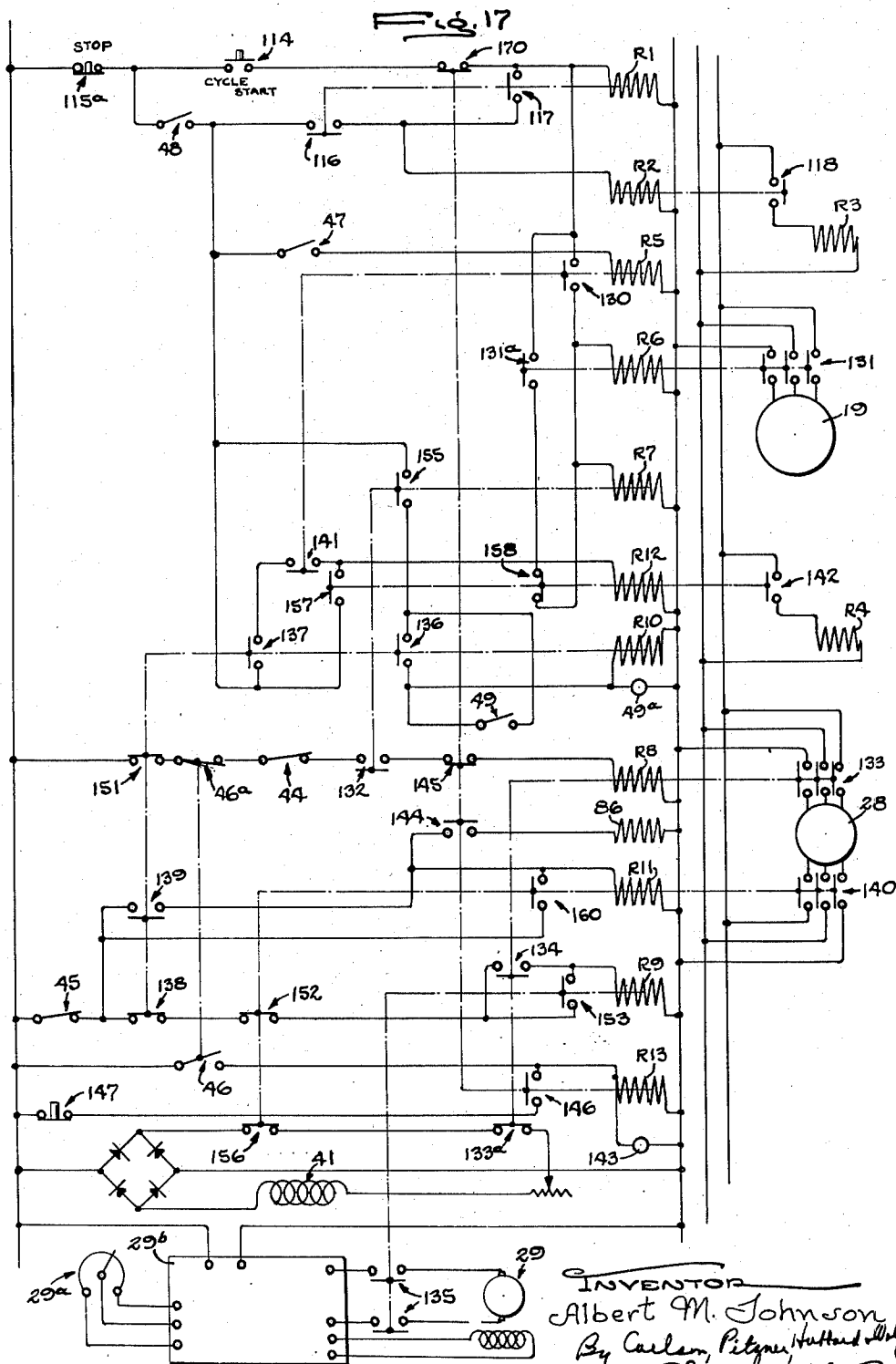
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HONE EXPANSION CONTROL MECHANISM

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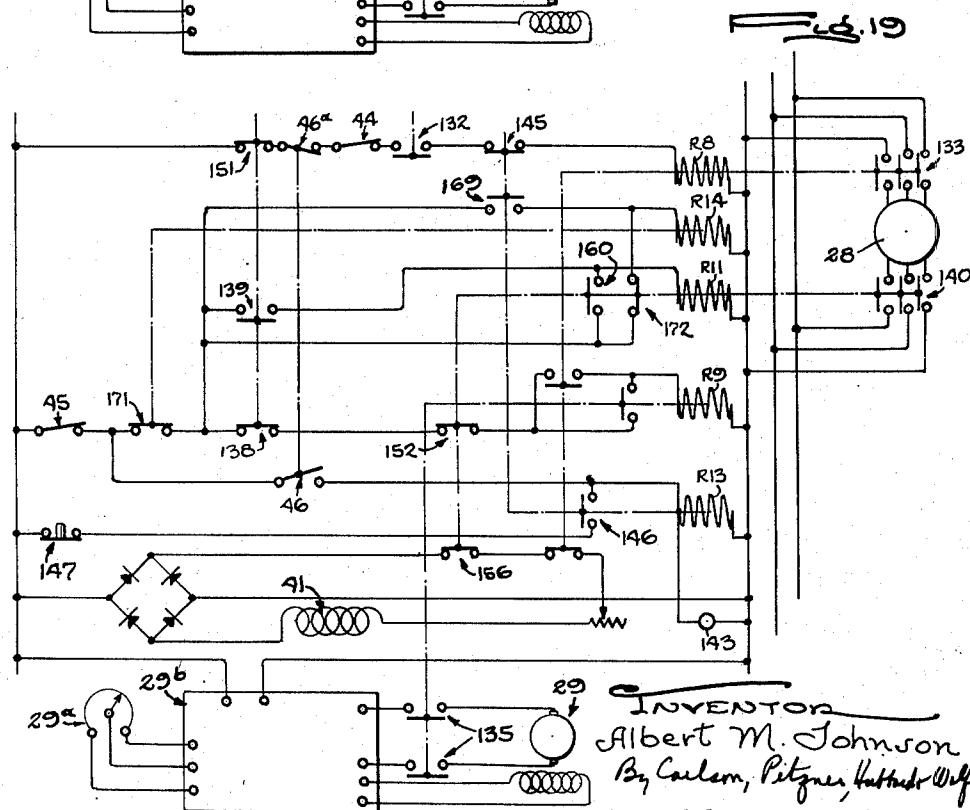
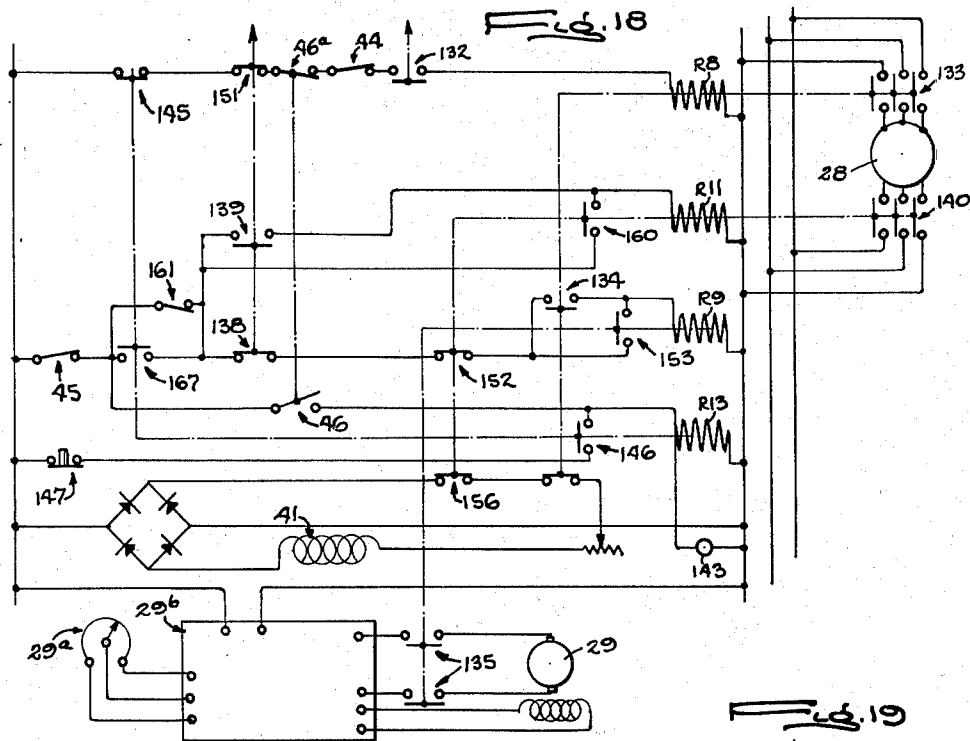
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HONE EXPANSION CONTROL MECHANISM

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2,819,566

HONE EXPANSION CONTROL MECHANISM

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Application January 3, 1956, Serial No. 557,116

9 Claims. (Cl. 51—184.3)

This invention relates to a high production machine for honing cylindrical surfaces on duplicate workpieces in successive cycles which, in the case of an internal work surface, consists in first rapidly expanding the honing tool within the work bore, continuing the expansion at a slow rate during reciprocation of the tool in the bore until the latter has been enlarged to the desired size, and then rapidly collapsing the tool preparatory to its withdrawal from the workpiece.

One object is to control the termination of the rapid expansion in a novel manner such as to minimize the time required for each honing cycle while at the same time avoiding engagement between the abrasive surface of the tool and the bore wall while the tool is being expanded at the rapid rate.

A more detailed object is to terminate the rapid expansion with the abrasive surface spaced short of the bore wall by an amount which remains substantially fixed in successive cycles irrespective of the wearing off of the abrasive surface.

The invention also resides in the novel manner of sensing the wearing off of the abrasive surface and correspondingly varying the successive cycles to interrupt the rapid expansion at the proper point in each cycle.

A further object is to utilize the improved control mechanism in a novel manner to signal wearing out of the abrasive elements of the honing tool.

Another object is to provide a novel means for conditioning the control mechanism for proper operation following replacement of worn out honing stones.

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

Figure 1 is a fragmentary elevational view, with certain parts in section, of a honing machine embodying the novel features of the present invention.

Fig. 2 is a fragmentary section taken along the line 2—2 of Fig. 1.

Fig. 3 is a schematic view and circuit diagram.

Fig. 4 is a fragmentary view taken along the line 4—4 of Fig. 2.

Figs. 5, 6, 7, 8 and 9 are views similar to Fig. 4 illustrating different positions of the principal parts, Fig. 9 being a section along the line 9—9 of Fig. 2.

Figs. 10 and 11 are fragmentary views showing the relationship of the abrasive and work surfaces at different points in a honing cycle.

Fig. 12 is a view similar to Fig. 4 showing a modification.

Fig. 13 is a fragmentary view similar to Fig. 2.

Fig. 14 is a view similar to Fig. 12 with the parts in a different position.

Fig. 15 is a view similar to Fig. 3 showing the modification of Fig. 12.

Fig. 16 is a view similar to Fig. 14 indicating the different positions of the parts in the honing cycle.

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Fig. 17 is an electric circuit diagram for use with the form of the invention shown in Fig. 3.

Fig. 18 is a similar diagram for use with the modification shown in Fig. 15.

Fig. 19 is a circuit diagram for another modification.

In the embodiment shown in the drawings for purposes of illustration, the invention is incorporated in a power actuated mechanism 10 (Figs. 1 and 3) for governing the expansion and contraction of a tool 11 for honing an internal cylindrical surface 12 of a workpiece 13 by reciprocation of the tool while the abrasive surface thereof is being pressed against the work surface. As in most production honing machines, the tool 11 is carried on the lower end of a spindle 15 journaled in a hollow head 16 slidable on vertical guide rods 17 (Fig. 1) mounted on the machine frame, parts of which are indicated at 18. The spindle is driven by an electric motor 19 (Fig. 3) mounted on the frame and connected to the spindle through suitable gearing and a spline shaft 20. Raising and lowering of the head to enter the collapsed hone into the work bore and withdraw the same therefrom and to reciprocate the expanded hone within the bore may be effected by an hydraulic actuator 21 mounted on the frame and supplied with pressure fluid from a motor driven pump 22 under the control of a reversing valve 23.

The honing tool is of a conventional type comprising a series of abrasive sticks or stones 24 angularly spaced around and frictionally held in a body 25 and normally engaging followers of conical cams 26. The latter are fast on a rod 27 which, in this instance, extends upwardly through the tool shank and the spindle 15. When the rod is moved downwardly, the stones are expanded against the bore wall 12, the outward pressure on the stones being continued while the spindle is rotated and reciprocated to enlarge the bore to the desired size. When the rod is moved reversely, the stones are allowed to move inwardly thus collapsing the hone.

While the expander rod 27 may be moved back and forth by various kinds of power actuators, the operator shown herein is of the electric type comprising motors 28 and 29 (Figs. 2 and 3) whose motions are combined by differential gearing 30 and converted into reciprocatory movement of the rod 27. The motors are carried by the tool head 16 and the motor 28 for producing the rapid expansion of the hone is coupled directly to the sun gear 31 of the differential which may as shown be of the planetary type. The speed of the motor 29 is reduced through a worm 33 meshing with teeth on the exterior of the ring gear 32. The spider or intermediate member of the differential carries planet gears 34 and is fast on a shaft 35 coupled through worm gearing 36 to a shaft 37 whose rotary motion is converted to endwise movement of the expander rod 27. While the conversion may be made through a screw mechanism, it is achieved herein by a pinion 38 on the shaft 37 meshing with a rack 39 on an extension of the expander rod 27.

The gear ratios are such that when both of the motors 28 and 29 are operating in a direction to move the rod 27 downwardly, the diameter of the hone at the working faces 40 of the stones 24 will be increased at a comparatively rapid rate, for example .047 of an inch per second. On the other hand, when the motor 29 alone is operating, the diameter of the abrasive surface of hone will be increased at a much slower rate, for example .00019 of an inch per second. This slow rate of expansion by the motor 29 may be varied by suitable means such as a rheostat 29^a (Fig. 17) for adjusting a speed controller 29^b, the speed selected corresponding approximately to the rate of wearing off of the stones when used to hone the particular work material.

Rapid contraction of the hone will occur when the

fast motor 28 is operating in the opposite direction. This raises the expanding rod 27 and the cams 26 thereby allowing the stones 24 to collapse. Quick stopping of the sun gear 31 when the motor 28 is deenergized is effected by energizing the winding of a magnetic friction brake 41 having one element 42 fast on the motor shaft.

Through the circuitry to be described later, the energization of the hydraulic actuator 21 and the motors 28 and 29 is controlled selectively to produce a cycle of operation which includes advance of the collapsed hone into the bore of a new workpiece clamped in the machine fixture, rapid expansion of the hone, continued slow expansion while the hone is being reciprocated throughout the length of the bore, collapse of the hone when the bore has attained the desired size and withdrawal of the collapsed hone to permit the finished workpiece to be removed from the machine and another workpiece substituted. Preferably, the shift from rapid to slow expansion, the initiation of the hone collapse, and the termination of such collapse are controlled by switches 44, 49 and 45 (Fig. 3) acting in conjunction with other switches 47 and 48 which respond to the reciprocatory movements of the tool head 16.

While the collapse of the hone may be initiated in other ways well known in the art, it is started in the present instance by a sizing device 50 (Figs. 1 and 3) which feels of the bore wall in the course of the honing and gives a suitable signal such as closure of the switch 49 when the bore has been enlarged to the desired size. Herein the sizing device comprises a sleeve 51 beveled at its lower end 52 and having an external diameter corresponding to the size of the bore to be sensed. The sleeve is urged downwardly by a spring 53 to a position determined by engagement between an external flange 54 and an abutment 55 on a bracket 56 which moves up and down with the head 16 and permits some degree of lateral floating of the sleeve 51 transversely of the bore. The arrangement is such that the sleeve end 52 reaches the upper end of the bore in the latter part of each down stroke of the head, the sleeve end engaging and centering itself in the end of the bore wall and dwelling there during the remainder of the stroke if the bore is undersize. In the next down stroke after the desired bore size has been attained, the sleeve enters the bore under the action of the spring and continues on with the head 16 until an arm 57 on the sleeve engages and actuates the switch 49 which, as shown in Fig. 1, is mounted on the machine frame 18.

In accordance with the present invention, the actuators for expanding and collapsing the honing tool are controlled in a novel manner such that the rapid expansion part of each cycle is, irrespective of the wear that has occurred in the previous cycles, terminated when the working faces 40 of the stones 24 reach a predetermined diameter 60 (Fig. 10) spaced only a short distance from the bore wall 12 but nevertheless before any contact occurs between the stones and the work. To this end, the rapid expansion is terminated by a control element such as the switch 44 which is actuated by a device 61 movable back and forth in unison with the hone expander 27 during the collapse and the initial expansion of the hone but joined to the expander by a coupling 62 which permits the device to be held against movement in the final or slow expansion of the hone while the stones thereof are in active engagement with the work.

Preferably the device 61 is associated with a rotating part of the hone expander, in this instance the shaft 37. Accordingly, the device comprises an elongated arm 63 having a hub 64 journaled on an extension of the shaft. A radial hole 65 drilled in the hub receives a shoe 66 (Figs. 4 and 6) urged against the shaft 37 by a spring 67 acting in compression against a screw 68. The shoe thus coacts with the hub to form a coupling frictionally gripping the shaft 37 with a torque determined by the stress of the spring 67. Thus when the arm is unob-

structed it swings back and forth with the shaft and follows the expansion and contraction of the working faces 40 of the honing stones.

The torque transmitted by the coupling 62 is sufficient to actuate the switch 44 which is mounted within the head 16 on a plate 69 (Figs. 2 and 4) with the actuating pin 70 disposed in the plane of oscillation of the arm 63 so as to be engaged and pushed inwardly to open the switch 44 when, during counterclockwise turning of the shaft 37, the arm 63 reaches the position shown in Fig. 5. This position is just short of a stop 71 formed by the rounded end of a screw 72 threading through a block 73 on the plate 69 and adapted to be advanced and retracted by turning a hand knob 74 which is exposed on the exterior of the head 16 and is adapted to be advanced in steps determined by a spring detent 75 (Fig. 2) coacting with notches in the periphery of the knob.

The stop 71 positively limits the counterclockwise swinging of the arm 63 and, when set for operation in the intended manner, is spaced beyond the point of actuation of the switch 44 by a distance a (Figs. 5 and 11) which corresponds approximately to the amount of stock to be removed from the interior of the bore in an average honing cycle. By cut and try adjustment of the stop 71, the width of the space a may be reduced to a minimum while at the same time insuring interruption of the rapid expansion of the hone just before the stone faces 40 reach the wall 12 of a work bore of minimum diameter.

After the arm 63 engages the stop 71 as shown in Fig. 6 and the expansion of the hone continues at the slow cutting rate, the coupling 62 slips and the shaft 37 continues to turn on ahead of the arm 63 until the bore has attained the desired size as determined by the sizing device 50. As a result of this slippage, the relationship between the arm 63 and the shaft 37 is changed in each cycle by an angle which corresponds substantially to the amount of wearing off of the stone surfaces during that cycle plus or minus the difference between the diameter of work bore and that of the bore of the previously honed workpiece. The device 61 is thus adjusted automatically in each cycle and conditioned to terminate the rapid expansion of the hone close to but short of the bore wall in the next cycle.

Closure of the switch 49 in response to the up-to-size signal interrupts the operation of the motor 29 and energizes the motor 28 for reverse operation to collapse the honing tool. Such collapse may be effected in various ways and with the hone at various diameters without appreciably affecting the overall length of the cycle. In the form shown in Figs. 1, 2, 3, and 18, the hone is collapsed fully in each cycle by retracting the expander rod to a limit position through the actuation of the switch 45 by an arm 77 spaced along the shaft 37 from the arm 63 and keyed or otherwise made substantially fast on this shaft. The switch is mounted on the plate 69 (Figs. 2 and 4) for some degree of adjustment to allow for changing the collapsed position of the expander rod 27. To facilitate conditioning of the control mechanism after replacement of a set of worn out stones, a screw stop 78 (Fig. 3) is mounted on the plate 69 and adjusted to a position to engage the fixed arm 77 just after the switch 45 is actuated during clockwise turning of the shaft 37 to collapse the hone.

It will be observed that the angular position of the shaft 37 at any time during active engagement of the stones and the bore wall 12 is a measure of the wear which has taken place. Thus, the fully worn out condition of the stones may be indicated by closure of a switch 46 by a roller on the end of an arm 80 (Figs. 2, 3, and 9) which turns with the shaft 37. The switch is fixed to the head 16 and the arm is fast on a sleeve 81 (Fig. 2) frictionally coupled through a spring 82 to the shaft 37 which supports the sleeve. By turning a knob 83 on the outer end of the sleeve, the position of the shaft at which the switch

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46 is actuated may be varied to suit different kinds or depths of stones that may be used in the tool.

In addition to signalling the worn out condition of the stones 24, closure of the switch 46 may be utilized to effect automatic resetting of the slip arm 63 preparatory to the starting of a new series of honing cycles following replacement of the worn out stones. To this end, an adjustable stop 85 (Fig. 4) is disposed in the plane of oscillation of the arm 63 on the side thereof opposite the stop 71, the stop 85 being normally retracted as shown in full in Fig. 4 but projected into the position shown in phantom in response to closure of the switch 46 and the later energization of a solenoid 86 (Figs. 2 and 4) on the tool head 16. The stop 85 is on the end of a rod 88 connected to the solenoid armature and slidable in a guide tube 87 threaded into a block 89 to provide a stop 90 engageable with a shoulder on the rod. When the solenoid is energized and the stop 85 projected to the limit position shown in full in Figs. 2 and 9 and in phantom in Fig. 4, the arm 63 is engaged and the torque of the friction of the coupling 62 is overcome thus shifting the arm to the new starting position which may be gauged with reference to the position of the fixed arm 77 when the latter is returned to the collapsed position (Fig. 8). In the ensuing honing cycle, the solenoid 86 is deenergized and the stop 85 retracted out of the way.

Operation

An automatic honing cycle utilizing the mechanism above described may be controlled by well known circuitry, a typical form of which is shown in Fig. 17. Assuming that one cycle has been completed, the parts of the mechanism and the control circuits will be conditioned as shown in Figs. 3 and 17 with the spindle drive motor stopped and the pump 22 running. The motors 28 and 29 are deenergized and the winding of the brake 41 is energized. The switch 48 is held open by a cam 112 on a disk 113 which, through a flexible two-way connection 114^a with the reciprocable head 16, is rocked back and forth during the advance and retraction of the tool head from the fully withdrawn position shown in Fig. 3.

After a new workpiece has been clamped in the machine fixture, a start switch 114 (Fig. 17) is closed manually to complete a circuit across the power lines and through a normally closed stop switch 115^a for energizing a relay R1 which closes its maintaining switch 116 and a switch 117 for energizing a relay R2 through the switch 117 and the start and stop switches. Energization of the relay R2 closes a switch 118 for energizing a solenoid R3 thereby shifting a valve 119 (Fig. 3) to the right so as to direct pressure fluid through a pilot valve 120 and a valve 122 which, by virtue of the deenergization of its solenoid R4, is positioned to direct pressure fluid to the right end of the plunger 121 of the direction control valve 23. The latter is thus conditioned to admit pressure fluid to the head end of the actuator 21 for initiating a downstroke of the tool head 16. In the initial part of this movement, the switch 48 is closed thus completing the holding circuit for the relay R1.

When, in the continued downward movement of the head 16, the collapsed honing tool reaches the lower end of the work bore 12, a lug 126 (Fig. 3) on the disk 113 will engage an arm 127 and turn the latter into engagement with a detent 127^a and also cause a cam surface 128 to swing a follower 129 and reverse the position of the pilot valve 120 and therefore the direction valve 23 causing the actuator 21 to start its upstroke. At the same time the follower lever 129 closes the switch 47 to energize a relay R5 through the then closed switches 48 and the stop switch 115^a. Closure of the switch 130 by the relay R5 energizes relays R6 and R7 through then closed switches 117, 116, 48 and 115^a. Energization of the relay R6 is maintained by its switch 131^a and closure by the relay of switches 131 starts the spindle drive motor 19.

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The upstroke of the head is terminated when a lug 143 on the disk 113 (Fig. 3) engages the arm 127 and moves the cam 128 away from the follower 129. This allows a spring 129^a to reverse the position of the pilot valve 120 and thus cause pressure fluid to again be delivered to the head end of the actuator 21. In this way, the hone is reciprocated back and forth in the bore 12.

Closure of the switch 132 by the relay R7 energizes the relay R8 through then closed switches 145, 44, 46^a and 151 thereby opening a switch 133^a to deenergize and release the brake 41 and closing switches 133 to energize the motor 28 and initiate rapid expansion of the honing tool. At the same time, the relay R8 closes a switch 134 and completes a circuit through then closed switches 152, 138, and 45 thus energizing the relay R9 which is held energized by a switch 153 and closes switches 135 for starting the slow expansion motor 29 which operates at a rate determined by the setting of an adjuster 29^a (Fig. 17) of a controller 29^b that determines the voltage applied to the motor. The motions of the two motors 28 and 29 are combined by the differential 30 and applied to the shaft 37 to turn the latter counterclockwise so as to lower the push rod 27 and expand the honing stones at the desired rapid rate. In this movement of the shaft 37, the arms 63 and 77 turn in unison with the shaft. This rapid expansion of the hone continues until the surfaces 40 of the stones reach the position 60 shown in phantom in Fig. 10 and disposed close to the bore wall 12. At this point, the arm 63 engages the actuating pin of the then closed switch 44 (Fig. 5) and opens the latter to break the energizing circuit of the relay R8 thus opening the switches 133 to stop the motor 28 and closing the switch 133^a to apply the brake 41.

Slow expansion of the hone is continued by the motor 29 alone. The stones first engage the bore wall 12 and by their honing action enlarge the bore wall in the usual way. At some point during this honing action depending on the rate of wearing off of the stones, the arm 63 engages the stop 71 as shown in Fig. 6 after which the coupling 62 starts to slip, the arm remaining against the stop 71 as shown in Fig. 7 as the shaft 37 and the fixed arm 77 continue on in the hone expanding direction until the bore is finished.

In the final part of each downstroke of the hone while engaging the work, the sizing plug 50 comes into feeling engagement with the upper end of the work bore wall 12 where it comes to rest and dwells in a centered position for the remainder of the stroke. The plug is lifted away from the bore during the latter part of each upstroke. Finally, on the downstroke following the enlargement of the bore to the desired size, the plug will enter the bore far enough to close the switch 49. This completes a circuit for energizing a signal lamp 49^a (Fig. 17) and a relay R10 to close switches 136, 137 and 139 and open the switches 138 and 151, the relay circuit extending from the relay through the switch 49, a switch 155 then closed by the relay R7, and switches 48 and 114. The switch 136 maintains the energization of the relay and the switch 151 prevents reenergization of the motor 28 in the expansion direction. Opening of the switch 138 results in deenergization of the relay R9 thus stopping the motor 29 to terminate the slow expansion of the hone.

Closure of the switch 139 completes a circuit through the then closed switch 45 for energizing the relay R11 to close its holding switch 160, to open a switch 156 by which the brake 41 is released, and to close switches 140 by which the motor 28 is energized for reverse rotation thereby initiating rapid collapse of the hone. The arms 63 and 77 then in the position shown in Fig. 7 move clockwise with the shaft 37, the arm 63 separating from the stop 71. When the shaft has turned far enough to bring the fixed arm 77 against the actuating pin of the switch 45 (Fig. 8), the latter is opened thus deenergizing the relay R11 to terminate the collapse with the arm 77 disposed substantially against the stop 78.

On the next upstroke of the hone following the up-to-size signal or closure of the switch 49, a circuit for energizing the relay R12 is completed through the then closed switches 141, 137, 48 and 114, the energization of the relay being held by its switch 157. Closure of a switch 142 by this relay energizes the solenoid R4 (Fig. 3) thereby shifting the valve 122 to the left so as to prevent reversal of the direction control valve 23 when the hone reaches the upper limit of its normal working stroke when the pilot valve 120 is reversed by engagement of a dog 143 with the arm 127. A switch 158 opened by energization of the relay R12 breaks the circuits of the relays R6 and R7 thus stopping the spindle drive motor 19 at the start of the withdrawing stroke of the hone. As a result, the upstroke of the hone by the actuator 21 is continued on beyond the normal honing range thereby fully withdrawing the collapsed hone out of the work bore. Such withdrawal is terminated when the switch 43 is opened by the dog 112 (Fig. 3). This deenergizes the relay R1 and therefore the relay R2 which in turn deenergizes the solenoid R3 allowing the valve 119 to return to the starting position under the action of its spring 159 (Fig. 3). The opening of the switch 48 and the resulting deenergization of the several relays returns the various switches to the condition shown in Fig. 17.

As the stones 24 wear away in successive honing cycles, the arm 80 on the shaft 37 moves farther and farther toward the switch 46 and closes the latter while opening the companion switch 46^a when the stones are fully worn out. At this time, the arm 63 has slipped relative to the shaft 37 and fallen behind the fixed arm 77 as shown in Fig. 9. Closure of the switch 46 energizes a lamp 143 (Fig. 17) to signal the worn out condition of the stones and also a relay R13 which opens a switch 145 to prevent reenergization of the motor 28 in the expanding direction. The relay R13 also closes a switch 144 to condition a circuit for energizing the solenoid 86 the next time the relay R11 is energized, in response to the up-to-size signal, in the next honing cycle to initiate rapid collapse of the hone and termination of that honing cycle. When the solenoid becomes energized the stop 85 is projected forwardly to the position shown in phantom in Fig. 4 so that during the ensuing rapid collapse of the hone, the arm 63 is blocked, the coupling 62 slipping during the remainder of the hone collapse motion. In this way, the arm 63 is shifted counterclockwise relative to the shaft 37 and thus returned to an angular position matching the fixed arm 77 as shown in Fig. 8. The arm 63 is thus conditioned for proper operation in the next honing cycle after the worn out stones have been replaced. To disable the expanding mechanism until the stones have actually been replaced, a switch 146 maintains the relay R13 energized until the mechanism is reset by opening a manually operable switch 147 to deenergize the relay R13.

Energization of the relay R13 also opens a switch 170 (Fig. 17) which is interposed in the circuit of the starting relay R1. Since the relay R13 is maintained energized by its switch 146, the entire hone expanding mechanism is disabled thus preventing the operator from starting another cycle until the manually operable switch 147 is opened to deenergize the relay. The failure of the cycle to start in the normal way indicates to the operator that the stones of the hone are worn out and should be replaced.

Modification—Figs. 12 to 16 and 18

It will be apparent that the expander rod 27 need not, in order to achieve the objectives mentioned above, be returned fully to its limit collapsed position in each honing cycle. Thus, the rapid collapse part of each cycle may be shortened and the control mechanism somewhat simplified by utilizing the arm 63 and its slip coupling 62 to stop the rapid motor 28 and terminate the rapid expansion part of the cycle.

For this purpose, a normally closed switch 161 is mounted on the plate 69 on the side of the arm 63 opposite the

switch 44 with its actuating pin 162 disposed in the plane of oscillation of the arm and adapted for engagement with the arm 63 shortly before the latter, in turning clockwise (Fig. 12) during rapid collapse of the hone, comes against an adjustable stop 163. The latter is formed by the end of a screw 164 threading through a block 165 on the plate 69.

As before, the switch 45 is arranged to be closed in response to full collapse of the honing tool as evidenced by return of the shaft 37 to a limit position corresponding to the unworn condition of a new set of honing stones. To effect such closure of the switch 45, another arm 166 is secured to the shaft 37 in a position such that a roller thereon engages the actuating pin of the switch 45 and closes the latter when the hone has, by clockwise turning of the shaft 37, been collapsed fully.

To enable the switch 161 to operate in the intended manner, the circuit above described is modified as shown in Fig. 18 by interposing the switch in series with the normally closed switch 45 and the switch 139 in the energizing circuit of the relay R11 by which the motor 28 is started to initiate rapid collapse of the hone following the up-to-size signal. Then, to permit of full withdrawal of the hone out of the work bore, the switch 161 is disabled by interposing a parallel switch 167 (Fig. 18) in the relay circuit.

In operation, the initial part of each honing cycle is executed in the manner detailed above including entry of the hone, reciprocation thereof in the work bore, starting of the spindle motor, rapid expansion of the hone starting with the parts positioned as shown in Fig. 15, and slow expansion of the hone until the up-to-size signal is given. Thus the arm 63 will have turned in unison with the expander shaft 37 and at the rapid expansion rate through the angle *b* (Fig. 16) when the motor 28 was stopped, moved on during slow expansion first through an angle *c* against the stop 71 where the arm dwells as shown in Fig. 16 during the actual honing of the bore while the shaft 37 is, due to wearing off of the stones, turned through an angle *d* before the up-to-size signal is given and the motor 29 stopped. At this time, the relays R1 to R7 and R10 will be energized as described above.

Closure of the switch 139 by the relay R10 completes the circuit through the then closed switches 45 and 161. The switches 140 are thus closed to start the motor 28 in a direction to turn the shaft 37 clockwise and rapidly collapse the hone. The arm 63 moves with the shaft until it encounters and actuates the pin 162 to open the switch 161 thereby deenergizing the relay R11. The motor 28 is thus stopped with the arm 63 disposed substantially against the stop 163 as shown in Fig. 15. The remainder of the cycle including stopping of the spindle motor and full withdrawal of the hone from the work bore is completed in the manner detailed above.

It will be apparent from the foregoing that except for variations in the diameter of the rough bores and different amounts of wear in the honing of successive workpieces, the shaft 37 will swing back and forth through substantially equal angles *e* in successive cycles, the range of such oscillation shifting progressively as the stones wear away. Finally, when the stones become worn out, the arm 80 on the shaft will have moved far enough to close the switch 46, the relay R13 is energized closing the switch 167 in parallel with the normally used rapid collapse switch 161. Now, when the motor 28, in response to the up-to-size signal, is started as above described, the rapid collapsing of the hone will not be terminated as before when the arm 63 opens the switch 161. Instead the arm comes against the stop 163 and the coupling 62 slips as the shaft 37 continues to turn and further collapses the hone; such collapse is continued until the arm 166 opens the switch 45 and stops the motor. The expander rod is then fully retracted and the hone fully collapsed preparatory to replacement of

the worn out stones after the head 16 comes to rest following full withdrawal of the hone to the position shown in Fig. 3. As before, the relay R13 remains energized and the expanding control mechanism disabled until the reset button 147 is depressed.

Modification—Fig. 19

With the circuit modified as shown in Fig. 19, the rapid collapse motion of the hone may be terminated short of the fully collapsed position by utilizing a timer to measure an interval substantially less than that required to turn the shaft 37 through its full range. The timer is a well known time delay relay R14 preferably of the flux decay type having a normally energized winding and a switch 171 which remains closed while the winding is energized and for an accurately measured short interval after the winding has been deenergized. The relay switch 171 is interposed in the circuits of the relays R9 and R11 and the relay winding is in a circuit extending through the switches 45, 171 and a switch 172 which is normally closed but opened by deenergization of the relay R11. For this modification, the switch 161 and the stop 163 for the slipping arm 63 are omitted.

The circuit thus modified operates as before to the point of energization of the relay R11 through the switches 45 and 171 in response to closure of the switch 139 by the relay R10 following the up-to-size signal. This starts the motor 28 to initiate rapid collapse of the hone and at the same time opens a switch 172 for deenergizing the time delay relay R14 which, after the lapse of the desired short interval, opens the switch 171. This deenergizes the relay R11 thus stopping the motor 28 and terminating the rapid collapse of the hone well before the shaft 37 has been returned to its fully collapsed position.

When the stones of the hone are worn out, the full withdrawal of the hone and disabling of the expanding is effected as above described by energization of the relay R13 as the switch 46 is closed by the arm 80. The relay R13 closes a switch 169 to establish an independent circuit for the time delay relay R14 through the switches 171 and 45. As a result, operation of the motor 28 is continued beyond the normal collapsed position and until the arm 166 on the shaft 37 opens the switch 45, the motor being stopped with the hone fully collapsed. The relay R13 continues to remain energized and, through its switch 170 (Fig. 17), disables the expanding mechanism until the manually operable switch 147 has been opened after replacement of the worn out stones.

It will be apparent that the slipping device including the arm 63, the coupling 62, and the stop 71 operates in a novel way to modify the action of the expanding mechanism in accordance with the wearing out of the honing stones so that the rapid expansion part of each cycle is terminated with the stone faces 40 close to but nevertheless out of actual contact with the bore wall. As a result, little time is lost in idle slow expansion of the hone and the overall length of the cycle is accordingly reduced.

I claim as my invention:

1. In a honing machine, the combination of, a hone adapted to enlarge a work bore by rotation and reciprocation therein, expanding mechanism including an element movable back and forth to respectively expand and contract said hone within a work bore, a power actuator selectively operable to move said element and cause expansion of said hone at rapid and slow rates or rapid contraction of the hone, means controlling said actuator to initiate said rapid expansion, a member having a slip friction coupling with said element and normally moved thereby in unison with said element, a device engageable by said member during expansion of the hone to control said actuator and change the expansion of the hone from said rapid to said slow rate, a stop disposed for engagement with said member at a point beyond the point of engagement whereby to block said member and cause slipping of

said coupling during the continued slow expansion of said hone, and mechanism for sensing changes in the diameter of a work bore being enlarged by said hone and controlling said actuator to initiate said rapid contraction of the hone when the bore has attained a predetermined size.

2. In a honing machine, the combination of, a hone adapted to enlarge a work bore by rotation and reciprocation therein, expanding mechanism including an element movable back and forth to respectively expand and contract said hone within a work bore, a power actuator selectively operable to move said element and expand said hone at rapid and slow rates, means controlling said actuator to initiate said rapid expansion, a member having a slip friction coupling with said element and normally moved thereby in unison with said element, a device engageable by said member during expansion of the hone to control said actuator and change the expansion of the hone from said rapid to said slow rate, a stop disposed for engagement with said member at a point beyond the point of engagement whereby to block said member and cause slipping of said coupling during the continued slow expansion of said hone, and mechanism for sensing changes in the diameter of a work bore being enlarged by said hone and controlling said actuator to interrupt said slow expansion when the bore has attained a predetermined size.

3. In a honing machine, the combination of, a hone adapted to enlarge a work bore by rotation and reciprocation therein, expanding mechanism including an element movable back and forth to respectively expand and contract said hone within a work bore, a power actuator selectively operable to move said element and expand said hone at rapid and slow rates, means controlling said actuator to initiate said rapid expansion, a member having a slip coupling with said element and normally moved thereby in unison with said element, a device engageable by said member during expansion of the hone to control said actuator and change the expansion of the hone from said rapid to said slow rate when the abrasive surfaces of said hone are disposed close to but short of contact with the wall of said bore, and a stop positioned for engagement with said member at a point beyond the point of engagement whereby to block said member and cause slipping of said coupling during the continued slow expansion of said hone.

4. In a honing machine, the combination of, a hone adapted to enlarge a work bore by rotation and reciprocation therein, expanding mechanism therefor including a shaft rotatable back and forth to respectively expand and contract said hone within a work bore, a reversible power actuator selectively operable to turn said element and cause expansion of said hone at rapid and slow rates or rapid contraction of the hone, means controlling said actuator to initiate said rapid expansion, an arm having a slip friction coupling with said shaft and normally movable in unison with said element, a device engageable by said arm during expansion of the hone to control said actuator and change the expansion of the hone from said rapid to said slow rate, and a stop disposed for engagement with said arm at a point beyond the point of engagement whereby to block said arm and cause slipping of said coupling during the continued slow expansion of said hone.

5. In a honing machine, the combination of, a hone adapted to enlarge a work bore by rotation and reciprocation therein, expanding mechanism therefor including a shaft rotatable back and forth to respectively expand and contract said hone within a work bore, a reversible power actuator selectively operable to turn said element and cause expansion of said hone at rapid and slow rates or rapid contraction of the hone, means controlling said actuator to initiate said rapid expansion, an arm having a slip friction coupling with said shaft and normally movable in unison with said element, a device engageable by said arm during expansion of the hone to control said actuator and change the expansion of the hone

from said rapid to said slow rate, a stop disposed for engagement with said arm at a point beyond the point of engagement whereby to block said arm and cause slipping of said coupling during the continued slow expansion of said hone, means controlling said actuator to interrupt said slow expansion and initiate rapid contraction of the hone, a second arm fast on said shaft, and a second device engageable by said second arm and operable to interrupt said rapid contraction when said hone has been fully collapsed.

6. In a honing machine, the combination of, a hone adapted to enlarge a work bore by rotation and reciprocation therein, expanding mechanism therefor including a shaft rotatable back and forth to respectively expand and contract said hone within a work bore, a reversible power actuator selectively operable to turn said element and cause expansion of said hone at rapid and slow rates or rapid contraction of the hone, means controlling said actuator to initiate said rapid expansion, an arm having a slip friction coupling with said shaft and normally movable in unison with said element, a device engageable by said arm during expansion of the hone to control said actuator and change the expansion of the hone from said rapid to said slow rate, a stop disposed for engagement with said arm at a point beyond the point of engagement whereby to block said arm and cause slipping of said coupling during the continued slow expansion of said hone, means controlling said actuator to interrupt said slow expansion and initiate rapid contraction of the hone, a second arm fast on said shaft, a second device engageable by said second arm and operable to interrupt said rapid contraction when said hone has been fully collapsed, a second stop disposed on the side of said first arm opposite said first stop for engagement with the first arm, and means for shifting said second stop into a position to engage said first arm and slip the latter relative to said shaft during the rapid collapse of said hone.

7. In a honing machine, the combination of, a hone adapted to enlarge a work bore by rotation and reciprocation therein, expanding mechanism for said hone including an element movable back and forth to respectively expand and contract said hone within a work bore and through a range between fully worn and fully collapsed positions, a power actuator selectively operable to move said element and produce expansion of said hone at rapid and slow rates or rapid contraction of the hone, means controlling said actuator to initiate said rapid expansion, a member having a slip friction coupling with said element and normally moved thereby in unison with said element, a device engageable by said member during expansion of the hone to control said actuator and change the expansion of the hone from said rapid to said slow rate, an adjustable stop disposed adjacent but spaced beyond said device for blocking engagement with said element, means automatically controlling said actuator

to initiate said rapid collapse of the hone, and a second similar device engageable with said member during said rapid collapse to terminate the operation of said actuator before said element reaches said fully collapsed position.

8. In a honing machine, the combination of, a hone adapted to enlarge a work bore by rotation and reciprocation therein, expanding mechanism for said hone including an element movable back and forth to respectively expand and contract said hone within a work bore and through a range between fully worn and fully collapsed positions, a power actuator selectively operable to move said element and produce expansion of said hone at rapid and slow rates or rapid contraction of the hone, means controlling said actuator to initiate said rapid expansion, a member having a slip friction coupling with said element and normally moved thereby in unison with said element, a device engageable by said member during expansion of the hone to control said actuator and change the expansion of the hone from said rapid to said slow rate, an adjustable stop disposed adjacent but spaced beyond said device for blocking engagement with said element, means automatically controlling said actuator to initiate said rapid collapse of the hone, a second similar device engageable with said member during said rapid collapse to terminate the operation of said actuator before said element reaches said fully collapsed position, and mechanism responsive to movement of said shaft to said fully worn position and operable to disable said second device during said rapid collapse and continue such collapse until said element reaches said fully collapsed position.

9. In a honing machine, the combination of, a hone adapted to enlarge a work bore by rotation and reciprocation therein, expanding mechanism for said hone including an element movable back and forth to respectively expand and contract said hone within a work bore and through a range between fully worn and fully collapsed positions, a power actuator selectively operable to move said element and produce expansion of said hone at rapid and slow rates or rapid contraction of the hone, means controlling said actuator to initiate said rapid expansion, a member having a slip friction coupling with said element and normally moved thereby in unison with said element, a device engageable by said member during expansion of the hone to control said actuator and change the expansion of the hone from said rapid to said slow rate, an adjustable stop disposed adjacent but spaced beyond said device for blocking engagement with said element, means automatically controlling said actuator to initiate said rapid collapse of the hone, and timing mechanism activated as an incident to starting of said rapid collapse and operable to stop said actuator before said element reaches said fully collapsed position.

No references cited.