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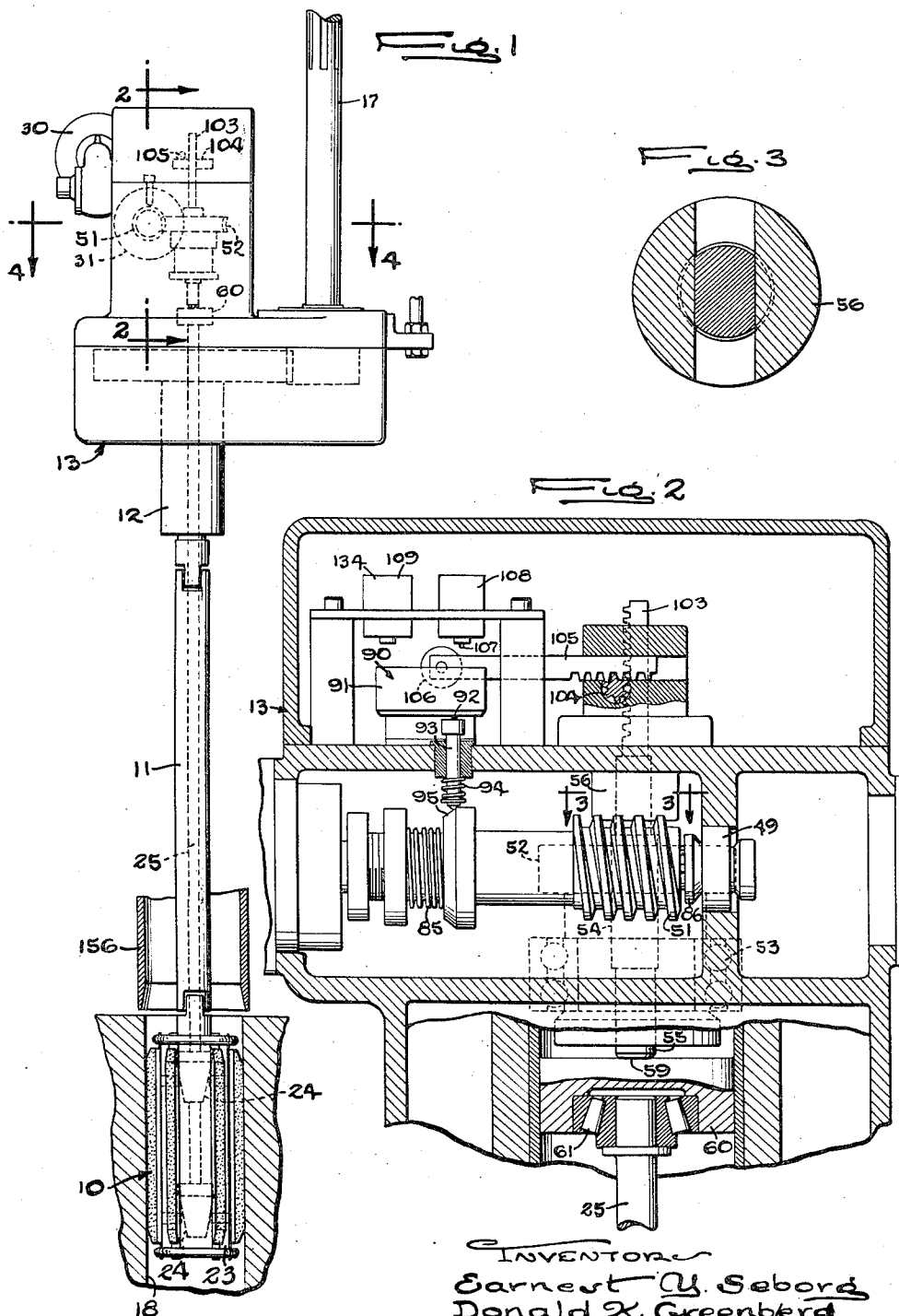
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2,780,893

HONING MACHINE

Filed March 4, 1953

6 Sheets-Sheet 1



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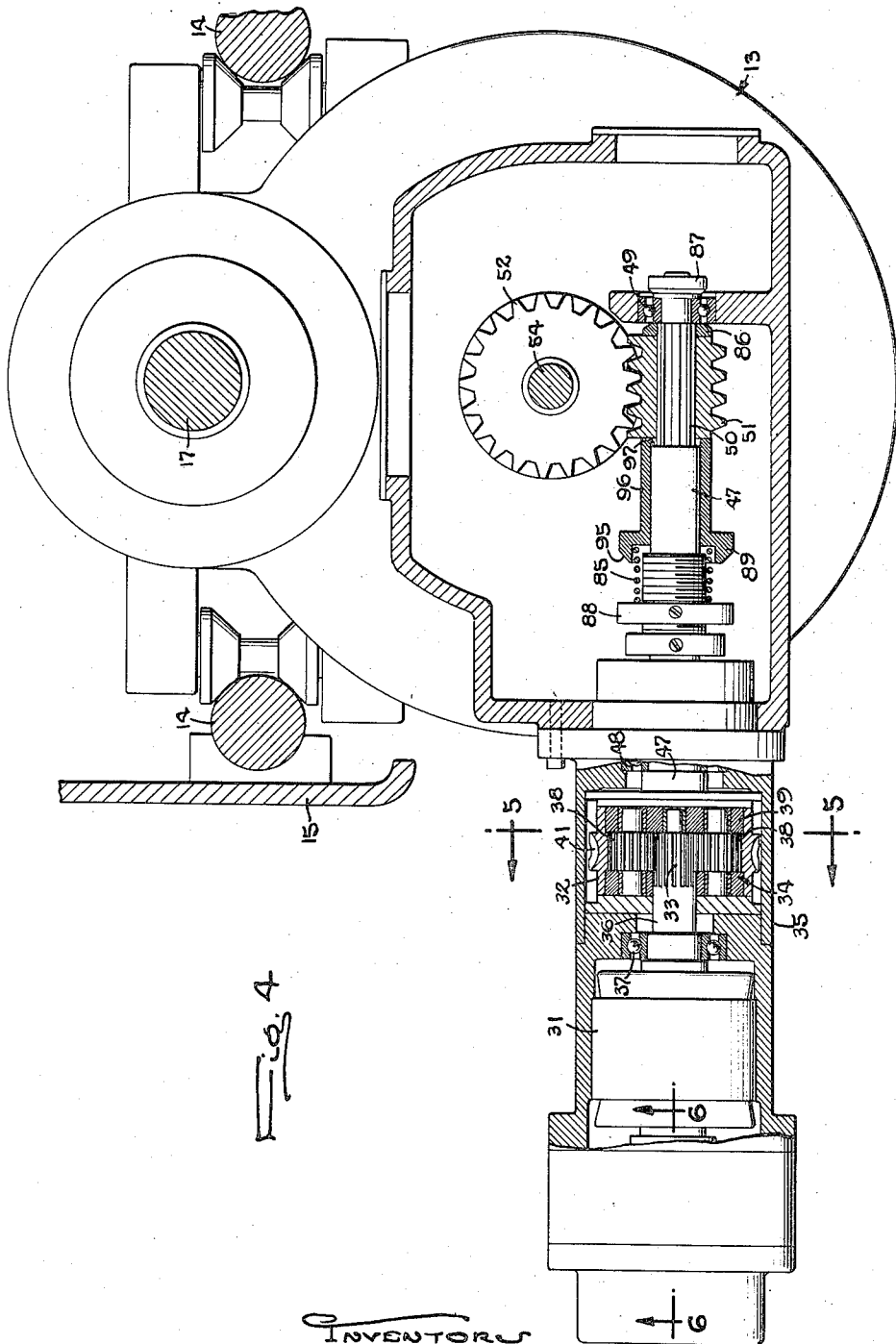
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HONING MACHINE

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6 Sheets-Sheet 2



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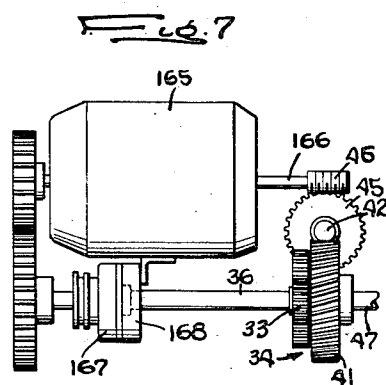
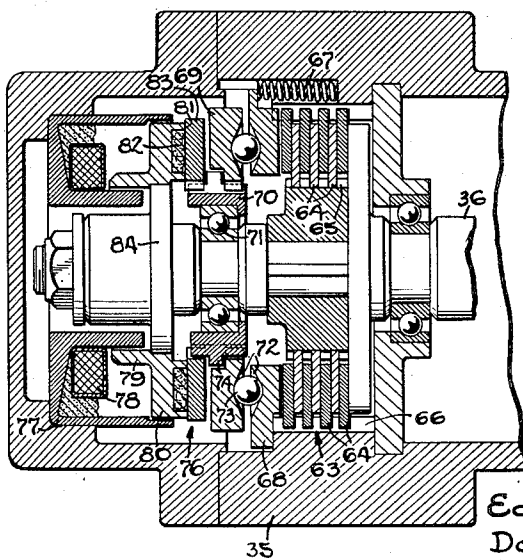
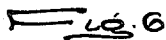
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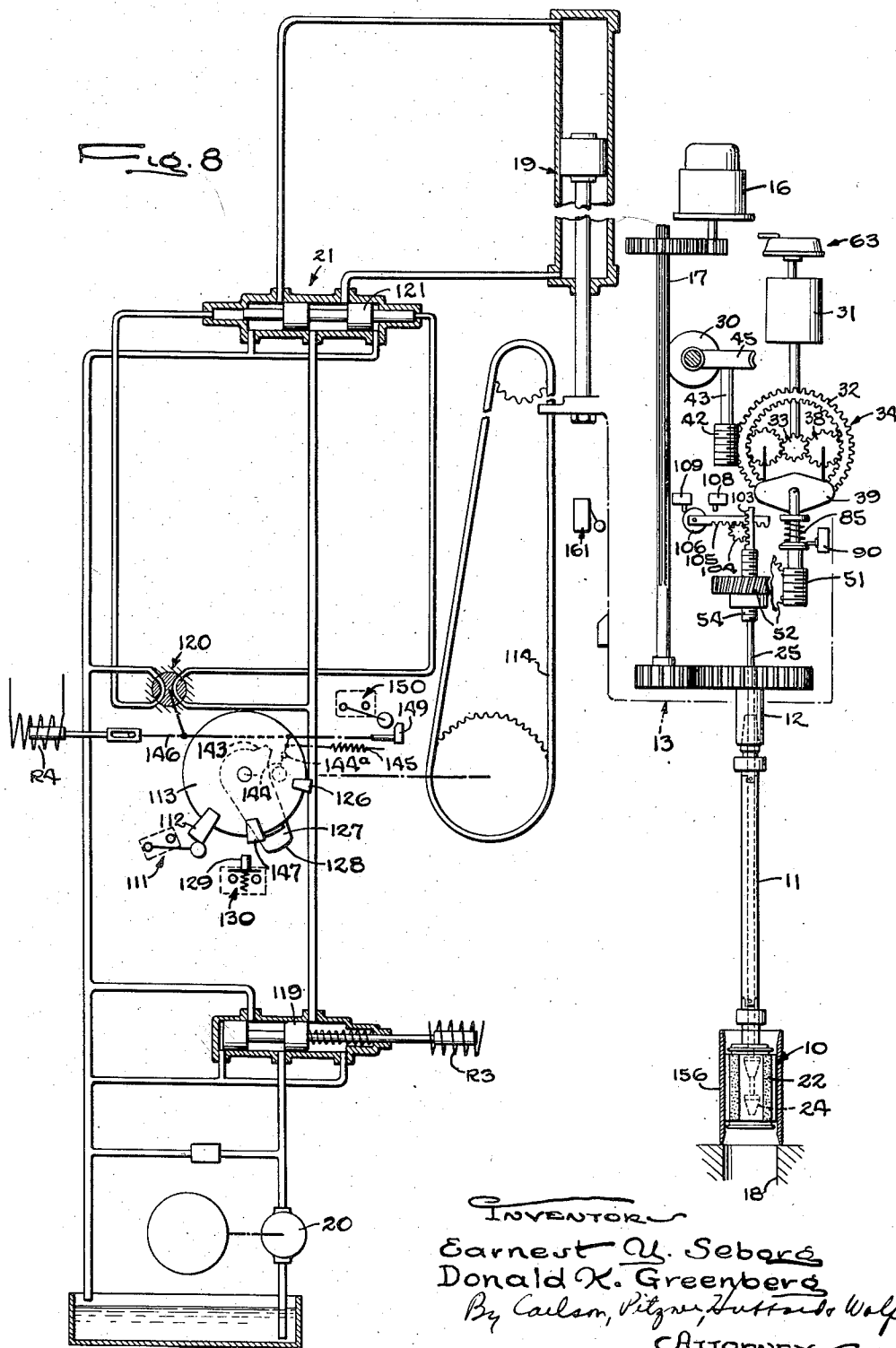
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HONING MACHINE

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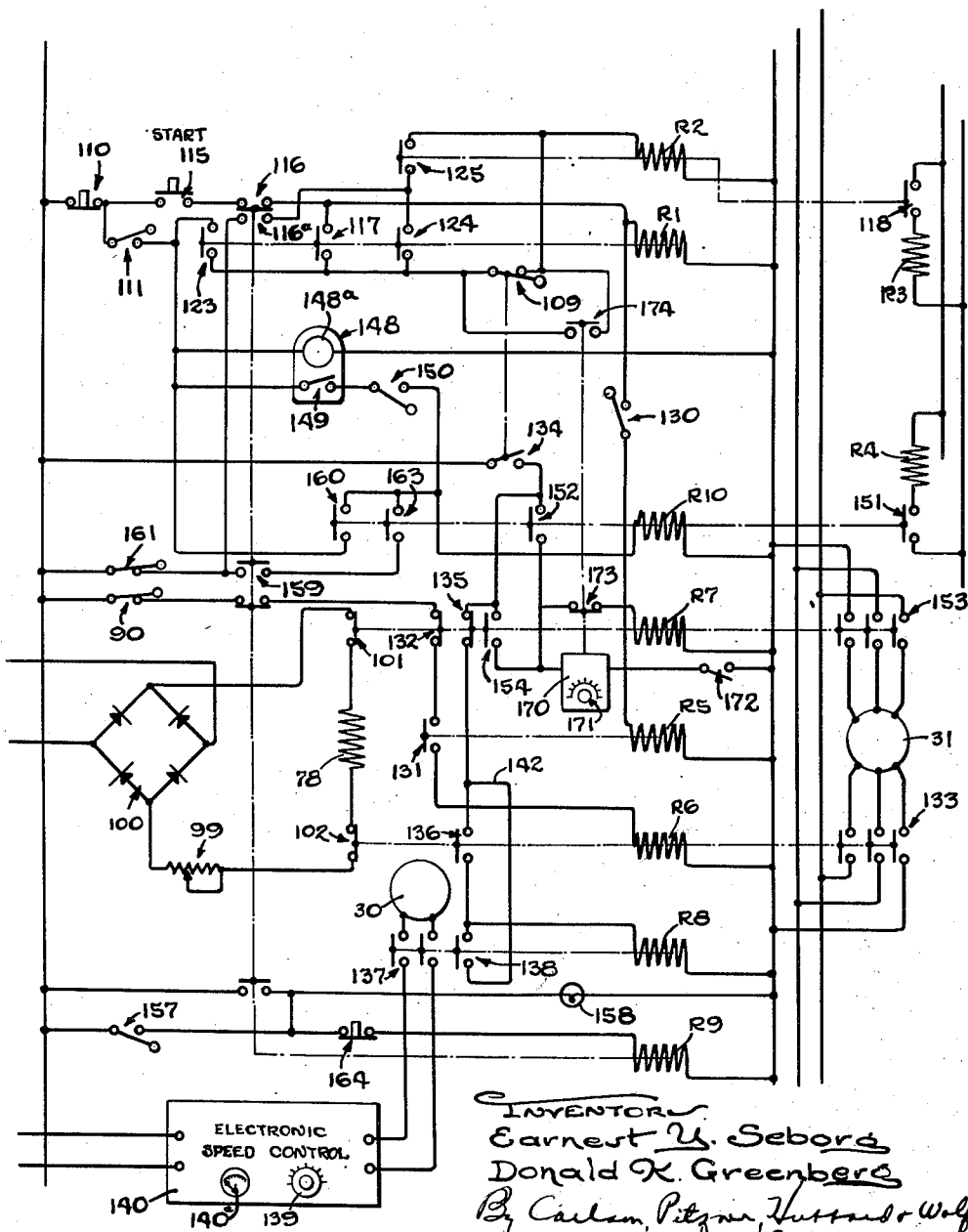
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HONING MACHINE

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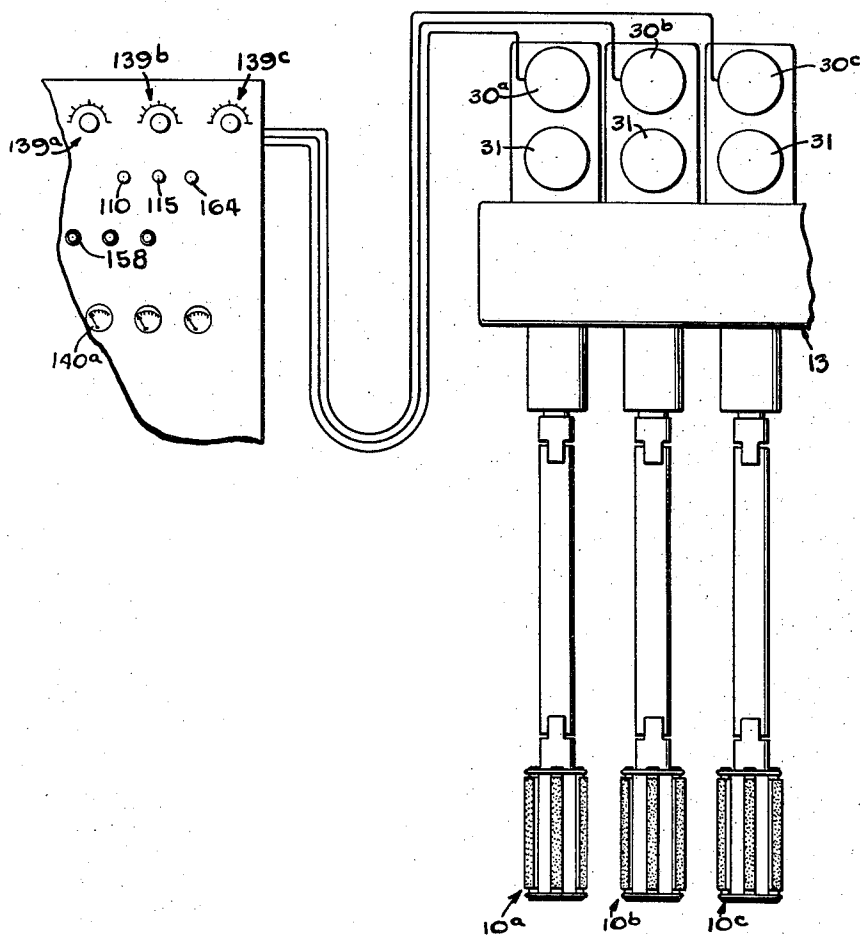
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Fig. 10



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HONING MACHINE

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Application March 4, 1953, Serial No. 340,232

14 Claims. (Cl. 51—34)

This invention relates generally to honing machines and more particularly a mechanism for expanding the hone after its entry into the work bore to effect expansion first at a rapid rate and then at a controlled rate during the enlargement of the bore.

The general object is to provide a more positive control of the hone expansion than has been possible heretofore, to expand the stones rapidly clear to the bore wall irrespective of the worn condition of the stones, and then to expand the stones at an accurately controlled rate corresponding to the rate at which the stone and work surfaces wear away.

Another object is to effect the hone expansion by high and low speed electric actuators and provide for interruption of rapid expansion in a novel manner in response to actual engagement between the honing stones and the wall of the work bore.

A more detailed object is to combine the motions of high and low speed electric operators and apply the same to the hone expander through the medium of a connection which includes a novel device for sensing engagement of the honing stones and the bore wall and interrupting the operation of the high speed operator.

A further object is to utilize the power operator for the hone expander in a novel manner to signal the wearing out of the honing stones.

Still another object is to incorporate in the hone expanding mechanism a novel means for limiting the maximum pressure that may be exerted on the stones.

A further object is to provide in a hone of the above general character a novel control for determining the duration of the hone collapse so as to shorten the time required for expansion of the hone when its stones have worn away.

The invention also resides in the novel manner of sensing the engagement of the stones and the work and in combining the motions of the electric operators to produce the desired rates of hone expansion.

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 of the head and tool of a honing machine embodying the novel features of the present invention.

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

Fig. 3 is a section taken along the line 3—3 of Fig. 2.

Fig. 4 is a fragmentary sectional view taken along the line 4—4 of Fig. 1.

Figs. 5 and 6 are fragmentary sections taken respectively along the lines 5—5 and 6—6 of Fig. 4.

Fig. 7 is a schematic view of the modified form of the drive mechanism.

Fig. 8 is a schematic view and hydraulic circuit diagram.

Fig. 9 is an electric circuit diagram.

Fig. 10 is a schematic view illustrating the use of the present invention in a multiple spindle honing machine.

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The improved hone expanding mechanism is particularly adapted for use in production type honing machines in which the honing tool 10 is carried on the lower end of a jointed shank 11 coupled to a spindle 12 journaled on a hollow head 13 which is slidable on vertical guide rods 14 (Fig. 4) mounted on the machine frame 15. The spindle is driven by an electric motor 16 mounted on the frame with its splined shaft 17 geared to the spindle. Raising and lowering of the head to enter and remove the collapsed hone into and out of the work bore 18 and to reciprocate the expanded hone within the bore may be effected by a hydraulic actuator 19 mounted on the machine frame and supplied with pressure fluid from a motor driven pump 20 under the control of a reversing valve 21.

The honing tool 10 comprises a series of stones 22 angularly spaced around a body 23 and normally held by springs against conical cams 24. The latter are fast on a rod 25 which extends upwardly through the tool shank and spindle 12. When the rod is moved downwardly, the stones 22 are expanded against the wall of the bore 18, the outward pressure on the stones being continued while the spindle is rotated and reciprocated to enlarge the bore to the desired size.

The present invention contemplates a new and improved electric motor actuated mechanism carried by the head 13 and operating after entry of the collapsed hone into the bore to move the rod 25 downwardly at a comparatively rapid rate until the stones actually engage the bore wall and then at a very slow rate precisely controlled and corresponding to the rate of wearing off of the stones and work material in the course of enlarging the bore. Generally stated, the expanding mechanism comprises two motor driven power sources whose motions are combined by a differential and applied to the rod 25, the high speed motion being interrupted abruptly in response to the development of a predetermined torque in the drive connection resulting from engagement of the stones 22 with the bore wall.

While the two speed power source may take various forms, it comprises in the present instance separate electric motors 30 and 31 mounted on the head 13 and coupled to the terminal members 32 and 33 of a planetary type differential gearing 34 mounted within a horizontally projecting tubular extension 35 (Fig. 4) of the head 13. The motor 31 is disposed in the outer end portion of this extension with its shaft 36 journaled in a bearing 37 and carrying at its end the sun gear 33 of the differential. This gear meshes with angularly spaced planet gears 38 whose shafts are journaled on the intermediate member 39 of the differential. The planet gears mesh with and support the ring gear 32 whose outer toothed periphery 41 is a worm wheel meshing with a worm 42 (Fig. 5). The latter is fast on a shaft 43 journaled in bearings 44 and carrying a worm wheel 45 driven by a worm 46 fast on the shaft of the motor 30 whose stator is secured to the exterior of the casing 35. It will be observed that the two worm gearings provide a substantial reduction in the speed of the motor 30 as applied to the differential which itself produces the desired reduction in the speed of the motor 31.

The spider or intermediate member 39 of the differential is fast on a shaft 47 (Fig. 4) journaled in a bearing 48 and projecting into the head 13 where its remote end is supported in a bearing 49. The splined end portion 50 of the shaft carries a worm 51 meshing with a worm wheel 52 journaled in bearings 53 (Fig. 2) to turn on a vertical axis. The wheel is threaded internally and forms a nut for a screw 54 on a shaft 55 slidable endwise in guides 56 (Figs. 2 and 3) by which the shaft and screw are held against turning. The lower end 59 (Fig. 2) of the screw shaft bears against a plug 60 slid-

able in the head 13 and supporting a thrust bearing 61.

It will be apparent from the foregoing that the rotary motions of the motors 30 and 31 are combined by the differential 34 and, after a further speed reduction by the worm gearing 51, 52 and the nut and screw 54, is converted into reciprocatory motion of the expander rod 25. The gear ratios are such that when both of the motors are operating in a direction to move the rod downwardly, the diameter of the hone 10 will be increased at a comparatively rapid rate, for example, .047 of an inch per second. On the other hand, when the motor 30 alone is operating, the diameter of the hone will be increased at a much slower rate, for example, .00019 of an inch per second. This slow rate of expansion is selected to correspond approximately to the rate of wearing off of one type of hone stone and the work material on which the hone is to operate and would be varied to suit given operating conditions. Such variation may be effected by manual adjustment of the knob 139 (Fig. 9) of a speed regulator 140 which may be an electronic unit commonly sold under the trade name of Thymotrol. Since the speed of the motor 30 corresponds to the voltage applied thereto, a voltmeter 140^a associated with the unit 140 so as to respond to the output voltage may be used to indicate the rate of expansion of the hone by the slow motor 30. This facilitates adjustment of the slow expansion rate and is particularly advantageous in correlating the rates of expansion of different hones in multiple machines.

Rapid contraction of the hone will occur when the fast motor 31 is operating in the opposite direction either alone or with the motor 30. In this case, as the expanding rod 25 is raised and the cams 24 retract, the honing sticks are collapsed by the usual garter springs.

Provision is made for stopping the sun gear 33 abruptly when the motor 31 is deenergized under conditions to be described later. This is accomplished herein by a friction brake 63 (Fig. 6) of well known construction comprising a plurality of friction disks 64 alternately splined at 65 to the outer end of the motor shaft 36 and at 66 into the head extension 35 and normally separated by springs 67 acting on an end ring 68 of the brake also splined into the housing. An axially slidable ring 69 is splined on a collar 70 carried by a bearing 71 supported by the shaft 36. A series of circumferentially sloping cam surfaces 72 on the rings 68 and 69 engage balls 73 and act thereon to permit retraction of the ring 68 when the ring 69 is in brake released position. In the movement of the ring in either direction away from this position, the ring is backed by a flange 74 on the collar 70 and the balls ride up the cam inclines causing the ring 68 to be shifted axially and press the plates 64 together thus applying the brake.

Such turning of the actuator ring 69 is effected by an electromagnetic friction pilot clutch 76 having a core 77 of U-shaped cross section stationarily mounted in the housing 35 and enclosing an annular winding 78. The concentric legs of the core telescope closely with inner and outer pole pieces 79 and 80 on a flange 84 having a hub keyed to the motor shaft 36. The pole pieces terminate in faces 81 separated by wear segments 82 and adapted for axial gripping engagement with an armature ring 83 splined on the collar 70. When the winding 78 is energized, magnetic flux threads a toroidal path through the core, the pole pieces and the armature and the rotating poles are drawn into engagement thus deriving a torque which turns the armature until the cams have applied the brake 63 whereupon the pilot clutch slips until the motion of the shaft 36 has been arrested. With the brake thus constructed, the motor shaft 36 will be stopped abruptly in response to energization of the winding 78.

In accordance with the present invention, novel means is provided for signaling the engagement of the honing stones with the bore wall during the rapid expansion of the hone and interrupting the circuit for the winding

of the higher speed power actuator before the stones are subjected to a crushing pressure, the slower speed actuator continuing to operate to expand the stones during actual honing of the bore. Preferably, this signaling means includes a control switch 90 (Fig. 2) actuated by a device which is yieldable in response to the building up of a predetermined torque in the drive connection to the hone expanding cams. While the yielding device may take various forms, it is shown herein as comprising the worm 51, its mounting for axial shifting, and a spring 85 (Figs. 4 and 8) urging the worm toward and normally holding the same against a stop 86 bearing against the bearing 49 which is held on the shaft 47 by a nut 87. The spring is coiled around the shaft 47 and acts between an adjustable collar 88 threaded onto the shaft and a flange 89 on the end of a sleeve 96 which bears at its other end against the inner end of the worm 51. By release of a locking screw and turning of the collar 88, the stress of the spring may be adjusted thereby varying the torque or expanding force at which the worm starts to yield after engagement of the stones and the bore wall.

The switch 90 includes contacts housed within a suitable casing 91 mounted on a partition of the head 13 for engagement of the actuating pin 92 of the switch with a plunger 93 slidable in the partition and urged by a spring 94 against a cam surface 95 on the yieldable sleeve. When the worm is in normal position against the stop 86, the follower 93 engages a low point on the cam thus allowing the switch 90 to remain closed. In the initial yielding of the spring following engagement of the honing stones and the work bore, the follower is shifted outwardly to open the switch which remains open while the remainder of the slack in yielding connection is being taken up by movement of the worm toward and against a stop shoulder 97 on the shaft 47. The amount of the slack as determined by the spacing of the shoulder 97 from the worm in the normal position shown in Fig. 4 is correlated with the adjustment of the spring 85 so that the time required for the worm 51 to reach the stop 97 after opening of the switch 90 and deenergization of the fast motor is less than the time required for the brake 63 to stop the fast motor 31.

The friction brake 63 operating as above described in conjunction with the differential gearing performs the additional function of adjustably limiting the pressure that may be exerted on the honing stones when engaging the work and being pressed outwardly by the action of the motor 30. In this connection, it will be noted that the reactionary torque prevailing in the drive connection between the motor 30 and the stones 22 when the latter are engaging the work is reflected backwardly through the differential 34 tending to cause slippage of the friction brake 63. The point at which slippage occurs is determined by the degree of energization of the winding 78 which remains energized during the slow expansion of the honing tool after the motor 31 has been deenergized. Therefore, by adjustment of the current applied to this winding, the point of slippage of the brake may be varied according to the maximum expanding pressure which it is desired to exert on the honing stones. There is therefore no danger of the stones becoming overloaded during a honing operation even though the rate of expansion of the stones by operation of the motor 30 does not match precisely the rate of wearing off of the stones. Such selective variation of the limiting torque above which the brake slips is effected by adjustment of a rheostat 99 (Fig. 9) in the energizing circuit of the brake winding which includes a source 100 of direct current and switches 101 and 102.

By virtue of the slow and accurately controllable rate at which the stones 22 may be expanded when actuated as above described by the motor 30 and the intermediate gearing, the rise of the cams 24 may cover the full wear range of the stones so that the axial position of the expanding rod 25 at any time corresponds to the extent

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the lower ends of the abrasive sticks 22 have been withdrawn from the work bore 18. Oscillation of the valve 120 back and forth in this manner by the action of the lugs 126 and 147 causes the hydraulic actuator 19 to raise and lower the expanding hone in the work bore 19. The shifting of the arm 127 by the lugs 126 and 147 is not sufficient to carry the cam surfaces 128 off from the follower 129 so that the switch 130 remains closed during the successive reciprocation of the tool.

Reciprocation of the hone in the bore 18 in this manner under the control of the oscillating disk 113 continues as the hone is being expanded at a slow and accurately controlled rate by the motor 30 whose operation may be interrupted in various ways as by a suitable gaging device for measuring the size of the bore 18 or after a predetermined number of reciprocations of the hone. To simplify the disclosure, let it be assumed that expanding of the hone is stopped after the lapse of a predetermined time interval measured by a suitable timer 148 (Fig. 9) and evidenced by closure of a switch 149. The timer may be driven by an electric motor 148^a which is started when the tool head actuated switch 111 is closed at the start of the cycle and stopped when this switch is opened upon withdrawal of the hone from the work bore to end a cycle. As is well understood in the art, the timer is of the type which resets itself automatically upon deenergization of the motor 148^a.

After closure of the timer switch and at the end of the next down stroke of the honing head 13 indicated by closure of the switch 150 by the cam 143 as described above, a circuit for energizing the relay R10 is completed through the stop switch 110 and the head actuated switch 111, the energization of the relay being maintained through a sealing circuit by-passing the switch 150 and including a switch 160 closed by the relay R10. When energized, this relay closes a switch 151 which connects the solenoid R4 across the source. As a result, the slide 146 is shifted to the left independently of the control disk 113 and the valve 120 is held independently in a position to cause raising of the head 13 to initiate full withdrawal of the hone from the work. A switch 152 is also closed by the relay R10 and completes a circuit through the switch 134 which is then closed by virtue of the expanded condition of the hone to energize a relay R7. Energization of the relay R7 opens the switch 101 to deenergize the winding 78 and thus release the brake. The relay closes the switches 153 for energizing the fast motor 31 to run the latter in a direction to raise the expander rod 25 and collapse the hone. In the initial reverse turning of the worm 52, the spring 85 shifts the sleeve 96 to open the torque sensing switch 90. Energization of the relay R7 also opens the switch 135 thereby interrupting the sealing circuit for the relay R8 by which the switches 137 are opened to stop the slow motor 30 of the expanding mechanism. The relay also opens a switch 132 to interpose a further break in the circuit of the expander relay R6. Another switch 154 is closed by the relay R7 to insure continued sealing of the relay R7 in the event that, because of some emergency, the full withdrawal of the hone is completed before full collapse of the hone. Normally, such collapse by the rapid action of the motor 31 is completed substantially instantaneously and well before the hone passes out of the work bore.

When, during operation of the fast motor 31 in the direction to reduce the external diameter of the hone, the expander rod 25 reaches a predetermined position as evidenced by movement of the roller 106 (Fig. 2) far enough to close the switch 109 and open the switch 134, the energizing circuit for the relay R7 is broken. This relay opens the switches 153 to stop the motor 31.

The relay R10 remains energized through the switch 160 until the head 13 has been raised far enough to withdraw the collapsed hone completely from the work bore, this position being determined by opening of the switch 111 by the cam 112 on the disk 113. The motor 148^a is thus deenergized to reset the timer and the relay R10

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is deenergized thus deenergizing the solenoid R4 to allow the slide 146 to be shifted by the spring 145 and thus restore the valve 120 to the position shown in Fig. 8.

The honing head 13 thus comes to rest with the hone 10 fully retracted from the work bore 18 but disposed within the usual guide sleeve 156 (Fig. 8) which, as is well understood in the art, is mounted on the work fixture slightly above the top of the work and operates to hold the rotating hone in position for proper entry into the next bore to be honed.

After a new workpiece has been placed in the fixture, a honing cycle may be initiated by again closing the manually operable switch 115. The cycle as described above is then repeated.

In the cycle as described above, collapse of the hone is effected by retraction of the expander rod 25 to a predetermined position irrespective of the extent of wear on the stones. The result is that as the stones wear away in successive cycles the rapid expanding and collapsing motions of the rod 25 are lengthened progressively. While the time interval required for these motions is relatively short, usually on the order of a few seconds, it may be desirable in some high production installations to reduce these delays. This may be achieved by the addition of a timer 170 (Fig. 9) arranged to be started coincident with the start of the motor 31 to initiate collapse of the hone and operating after the lapse of a shorter interval which will be only a fraction of a second to effect deenergization of the relay R7. As a result, the collapsing movement of the rod 25 will be of substantially equal lengths as determined by the accuracy of the timer 170 although these movements are not measured by or related to the wearing of the stones.

The timer 170 may be of the well known flux decay type and the interval measured may be varied by adjusting a hand knob 171. The winding of the timer is energized through a circuit which includes the switch 134, the switch 152 above described, and a hand switch 172, which is closed to render the timer active in determining the extent of collapse of the hone. When the timer winding is energized, the timer is reset and measurement of the desired interval is started. At the time of this interval, a normally closed switch 173 is opened to effect deenergization of the relay R7 and interruption of the operation of the motor 31. At the same time, a timer closes a normally opened switch 174 which is arranged in parallel with the switch 109 so as to perform the functions of the latter switch when the modified control by the timer is rendered active by closure of the hand switch 172.

Normally when the stones 22 of the hone are relatively new, the rod 25 will not move far enough during its hone expanding movement to carry the roller 106 (Fig. 2) into engagement with the actuator for the switch 108. However, as the stones wear down, the roller moves closer and closer to the switch in the successive honing cycles and eventually closes the switch. This constitutes an indication that the stones are worn out and should be replaced. Herein, closure of the switch may complete a circuit for an electric lamp 158 thus giving a visual signal to the operator.

In one of its more limited aspects, the invention contemplates utilization of the closure of the switch 157 to energize the relay R9 which, to control the tool head actuator 19 and, at the end of the cycle, causes the tool 10 to be withdrawn beyond its normal stopped position within the guide sleeve 156 to a position in which the stones 22 are free and easily removable. To this end and after the normally acting stop switch 111 is opened, the energization of the withdraw relay R10 is maintained through a parallel circuit which is completed by closure of a switch 159 by the relay R9 and extends through a switch 163 which is closed in the initial energization of the relay R10 and a switch 161 which responds to the movement of the tool head 13 and remains closed until, in the upward or withdrawing movement

to which the stones have worn away. Accordingly provision is made for utilizing the movement of the expander rod to signal the wearing out of the stones. To this end, the extended upper end 103 (Figs. 2 and 8) of the rod is formed with rack teeth meshing with a pinion 104 which in turn meshes with a rack bar 105 mounted on the head 13 for endwise sliding movement. At its outer end, the bar carries a roller 106 which in the fully expanded condition of the honing tool engages the actuating pin 107 of a switch 108 whose closure constitutes a signal that the honing stones are worn out and should be replaced. A switch 109 also mounted in the head 13 is positioned to be closed by the roller 106 when the expander rod 25 is in its upper limit position, the honing tool then being fully collapsed.

If desired, the fast and slow speed hone expanding motions above described may be derived from a single motor 165 (Fig. 7) which may constitute a common part of the fast and slow actuators above described for expanding and collapsing the honing tool. For example, one end of the motor shaft 166 may be coupled to the ring gear 41 of the differential to produce slow expansion of the hone when the motor is energized to run in one direction. The motion of the other end of the shaft is transmitted through an electromagnetic friction clutch 167 of well known construction to the sun gear 33 of the differential whenever the winding of the clutch is energized simultaneously with the motor 165. At the same time, an electromagnetic brake 168 applied to the driven element of the clutch is deenergized so that the high speed motion is added to the slow speed drive to expand the hone rapidly. In response to closure of the switch 90 by engagement of the honing stones with the bore wall, the clutch 167 would be deenergized and the brake 168 would be applied. Similarly, collapse of the hone in response to closure of the switch 150 would involve energization of the motor 165 for reverse operation combined with energization of the clutch 167 and deenergization of the brake. In all other respects, the control of the electric expanding actuator is the same as in the case of the form first described.

Operation

Energization and deenergization of the power actuators for expanding and contracting the hone occur at proper times in the automatic cycle of the honing machine which may be governed by well known mechanism a typical form of which is shown in Fig. 8. Assuming that a cycle has been completed, the parts and control circuits will be conditioned as shown in Figs. 8 and 9 with the spindle drive motor stopped and the pump 20 running. The motors 30 and 31 are deenergized and the winding 78 of the brake 63 is energized. A switch 111 is held open by a cam 112 on a disk 113 which is rocked back and forth through a flexible two way connection 114 with the reciprocable head 13.

After a new workpiece has been clamped in the fixture, a start switch 115 is closed manually to complete a circuit across the A. C. power lines for energizing the relay R1 through a normally closed stop control switch 110 and a then closed switch 116 of the relay R9. The resulting closure of a switch 117 completes a circuit for energizing a relay R2, this circuit extending through the start switch 115, the switches 116, 117, and the switch 109 which as above described is closed when the hone is collapsed.

Energization of the relay R2 closes a switch 118 which connects a solenoid R3 across a current source thereby shifting a valve plunger 119 (Fig. 8) to the right against the action of its spring. This admits high pressure fluid to the valve 21 and to a valve 120 which, by virtue of the deenergization of the solenoid R4 is positioned to direct pressure fluid to the right end of the valve plunger 121 and shift the latter to the left. This results in the admission of pressure fluid to the upper end of the cylin-

der 19 and the initiation of downward movement of the honing head 13. In the initial part of this movement during which the disk 113 is turned clockwise, the cam 112 passes the actuator for the switch 111 and allows the latter to close thereby completing a locking circuit for the relay R1 through the stop switch 110, a sealing switch 123 closed by relay R1 and also a locking circuit for the relay R2 through the then closed switches 124 and 125.

When, in the continued downward movement of the head 13, the honing tool reaches the lower end of the work bore 18, a lug 126 on the disk 113 will engage an arm 127 and shift the latter about the disk axis so that a cam surface 128 engages a follower 129 to close a switch 130. Through the then closed switches 110, 111, 123 and 117, this completes a circuit in parallel with the relay R1 for energizing a relay R5 thus closing a switch 131 by which a relay R6 is energized through a circuit including the then closed torque responsive switch 90 described above and a closed switch 132 of a then deenergized relay R7. The relay R6 opens the switch 102 to deenergize the winding 78 and thus release the electric brake 63 and also closes switches 133 for energizing the high speed motor 31 to run the latter in a direction to shift the rod 25 and expand the hone 10 rapidly. In the initial part of the ensuing movement of the expanding rod 25, the switch 109 is opened by withdrawal of the roller 106 (Fig. 2) and a companion switch 134 is closed, the latter completing a circuit which extends through a normally closed switch 135 of the relay R7, a switch 136 then closed by the relay R6, and a relay R8. Such energization of the latter closes switches 137 for energizing the slow speed motor 30 and also a switch 138 for maintaining the energization of the relay R8. The motor 30 thus runs along with the fast motor 31 at a speed determined by the setting of the speed adjusting knob 139.

With the motors 30 and 31 both operating, the rod 25 is shifted downwardly and the honing tool is expanded to the full size of the work bore in a small fraction of a second. As soon as the rapidly expanding stones 22 encounter the bore wall, the torque in the driving connection builds up rapidly. When it attains a value sufficient to overcome the spring 85, the worm 51 and the sleeve 96 shift axially and, in their initial movement, open the switch 90 thereby breaking the holding circuit for the relay R6 which is deenergized to open the switches 133 and stop the fast motor 31 and to close the switch 102 to energize the brake 63. The fast motor is stopped abruptly before the honing stones 22 have been subjected to substantial pressure. The operation of the slow speed motor 30 continues by virtue of its sealing circuit for the relay R8 which extends through the switch 138 and through a conductor 142 by-passing the switch 136.

As the slow expansion of the hone at the preselected rate continues, the hone is reciprocated back and forth through the work bore 18 in the following manner. As the hone 10 approaches the lower end of the bore 18, the lug 126 on the disk 13 shifts the arm 127 far enough in a clockwise direction to cause a lug 143 (Fig. 8) on the hub of the arm to cam a follower lever 144 outwardly about its fulcrum 144^a and the action of a contractile spring 145, thus shifting a slide 146 to the left thereby reversing the position of the valve 120 whose actuating arm is connected to the slide. In this movement, a lug 149^a (Fig. 8) on the slide 146 closes a switch 150, this being a signal that the honing tool is at the lower end of its stroke. As a result of reversal of the valve 120, pressure fluid is directed to the left end of the plunger 121 and the valve 21 is shifted to direct pressure fluid to the lower end of the cylinder 19 thereby initiating raising of the honing head 13. This turns the control disk 113 counterclockwise until a lug 147 on the latter engages the opposite side of the arm 127 and moves the latter to carry the lug 143 away from the follower 144 and allow the spring 145 to shift the valve 120 to the reverse position. A downward stroke of the hone is thus initiated before

of the head, the tool 10 reaches a position above and outside of the guide sleeve 156. The relay R2 also remains energized through a branch circuit 165 which includes a switch 116^a closed by the relay R9. In this instance, the switch 161 is closed by a cam 162 positioned on the tool head 13 to engage and open the switch 161 at a position of the head somewhat above the normal withdrawn position shown in Fig. 8 and determined by opening of the switch 111 by the cam 112. Opening of the switch 161 breaks the circuit for the relays R10 and R2 thus deenergizing the solenoids R4 and R3 to reverse the valves 120 and 119 and stop the head 13 as described above. When the hone has been stopped in this upper position, all of the stones 22 are readily accessible for removal from the hone body. After replacement of the worn out stones, another cycle may be initiated in the regular way above described by closure of the cycle start switch 115 after deenergization of the relay R9 by manually opening a switch 164.

The improved mechanism above described eliminates many of the disadvantages inherent in prior production honing machines and is substantially more versatile in the functions that may be performed. The rapid expansion of the honing stones is carried all the way to the wall of the work bore and the slow expansion is continued immediately at a rate which is not influenced by changing operating conditions such as the viscosity of a motivating fluid. Being derived from an electric motor which operates at a constant rate through selectively adjustable speed, the slow expansion is positive and may be correlated accurately with the rate of wearing off of the stones and bore wall under given operating conditions. As a result, the actuating mechanism may be adapted for removal of the necessary stock at an optimum rate thereby affording maximum production capacity of the honing machine.

Because the rapid expansion and collapse is effected by a separate power actuator, it may take place at high speed, and the collapse need not be controlled accurately nor related to the extent of wear on the stones. The electric motors 30 and 31 may be of relatively small size even in larger size honing machines, thus contributing to the low cost construction. Since these motors are controlled electrically, numerous auxiliary functions may be performed at a low additional cost including automatic sizing as by simple work bore feelers, the indication of wearing out of the stones, limitation of the pressure exerted on the stones, variation of the extent of collapse of the hone in each cycle, prolonged reciprocation of the expanded hone within the work bore to effect so-called "sparking out," and withdrawal of the hone an extra distance after the stones have worn out.

A special advantage of the improved hone expanding mechanism obtains in multiple tool honing machines in which it is desirable to conclude substantially simultaneously the operation of the individual hones 10^a, 10^b, 10^c carried on a common reciprocable head 13 as shown diagrammatically in Fig. 10. With the present invention, the rate of expansion of the stones in removing stock from the respective work bore is determined by the speeds of the associated motors 30^a, 30^b, and 30^c which may be controlled by speed regulators 140 having individually adjustable control knobs 139^a, 139^b, 139^c. Thus, if a greater time is required for the hone 10^b to complete the removal of a given amount of stock from the work bore, the rate of expansion of the other hones 10^a and 10^c may be reduced by adjustment of the associated speed regulators until, under the prevailing operating conditions, the automatic cycles of the respective tools are substantially equalized.

We claim as our invention:

1. In a honing machine, the combination of, an expandible honing tool, having a plurality of work engaging elements, a head supporting said tool and reciproca-

ble to carry the latter into and out of a work bore to be honed, means including a member coupled to said elements and mounted on said head for movement back and forth to expand and contract said hone, an electric motor, a second electric motor having a brake applied and released automatically as an incident to deenergization and energization of the motor, a differential combining the motions of said motors and having an output element rotatable in accordance with the resultant of said motions, a motion transmitting connection between said element and said member including a part yieldably urged into a predetermined position but movable out of said position in response to the building up of a predetermined torque in said connection following engagement of said honing elements with the wall of said work bore during expansion of said tool, means for energizing said motors to initiate expansion of said hone, a switch responsive to yielding of said part and movement thereof out of said position, and mechanism controlled by said switch and operable in response to such actuation thereof to deenergize said second motor while maintaining continued energization of said first motor and thereby continue the expansion of said tool.

2. In a honing machine, the combination of, an expandible tool having honing elements, a reciprocable head carrying said tool, means including a member coupled to said elements and mounted on said head for movement back and forth to expand and contract said hone, an electric motor, a second electric motor having a brake applied and released automatically as an incident to deenergization and energization of the motor, a differential having input elements actuated by the respective motors and an output element rotatable in accordance with the resultant of input movements, a motion transmitting connection between said output element and said member including a part yieldably urged into a predetermined position but movable out of said position in response to the building up of a predetermined torque in said connection following engagement of said honing elements with the wall of said work bore during expansion of said tool, a switch responsive to yielding of said part and movement thereof out of said position during expansion of the hone, and mechanism controlled by said switch and operable in response to such actuation thereof to deenergize said second motor and continue the expansion of said tool by said first motor.

3. In a honing machine, the combination of, an expandible honing tool having abrasive elements, a reciprocable head carrying said tool, means including a member coupled to said elements and mounted on said head for movement back and forth to expand and contract said hone, a power operator, an electric motor, a differential having input elements actuated by said operator and motor and having an output element, a motion transmitting connection between said output element and said member including a part yieldably urged into a predetermined position but movable out of said position in response to the building up of a predetermined torque in said connection following engagement of said honing elements with the wall of said work bore during expansion of said tool, means responsive to yielding of said part and movement thereof out of said position, and mechanism controlled by said last mentioned means and operable in response to such actuation thereof to deenergize said motor and then continue the expansion of said tool by said operator.

4. In a honing machine, the combination of, an expandible honing tool having abrasive elements engageable with the wall of a bore being honed by the tool, a reciprocable head carrying said tool, means including a member coupled to said elements and mounted on said head for movement back and forth to expand and contract said hone, a power operator, an electric motor, a differential having input elements actuated by said operator and motor and an output element, a motion transmitting connection between said output element and said member, means for sensing the building up of a predetermined torque in said con-

nection following engagement of said honing elements with the wall of said work bore during expansion of said tool, and mechanism controlled by said last mentioned means and operable to interrupt the operation of said motor and effect operation of said operator when said predetermined torque has been attained to further expand said honing elements.

5. In a honing machine, the combination of, an expandible honing tool having abrasive elements engageable with the wall of a work bore, a head supporting said tool and reciprocable to carry the latter into and out of a work bore to be honed, means including a member coupled to said elements and mounted on said head for movement back and forth to expand and contract said hone, separate rotary power operators each having an electromagnetic winding adapted when energized and deenergized to render its associated operator active and inactive respectively, rotary drive mechanism for transmitting the motions of the respective operators to said member at a rapid rate or at a slow rate, said drive mechanism including an element normally held yieldably in one position but movable out of said position in response to the building up of a predetermined torque in the transmitting mechanism following engagement of said honing elements with the wall of the work bore during expansion of said tool, and mechanism responsive to such yielding of said element to deenergize the winding of said rapid operator while causing energization of the winding of the slow operator to further expand the tool.

6. In a honing machine, the combination of, an expandible honing tool having abrasive elements engageable with the wall of a work bore, means including a member coupled to said elements and mounted on said head for movement back and forth to expand and contract said hone, separate rotary power operators each having an electromagnetic winding adapted when energized and deenergized to render its associated operator active and inactive respectively, rotary drive mechanism for transmitting the motions of the respective operators to said member at a rapid rate or at a slow rate, means signalling the building up of a predetermined torque in said drive mechanism following engagement of the expanding honing elements with the wall of said work bore, and mechanism operable in response to the torque signal to deenergize the winding of said rapid operator while causing energization of the winding of the slow operator to further expand the honing tool.

7. In a honing machine, the combination of, an expandible honing tool having abrasive elements engageable with the wall of a work bore, a head supporting said tool and reciprocable to carry the latter into and out of a work bore to be honed, means including a member coupled to said elements and mounted on said head for movement back and forth to expand and permit contraction of said hone, separate rotary power operators each having an electromagnetic winding adapted when energized and deenergized to render its associated operator active and inactive respectively, rotary drive mechanism for transmitting the motions of the respective operators to said member at a rapid rate or at a slow rate, means operable during expansion of the tool by the rapid operator to signal actual engagement of said honing elements and said wall of the work bore, and mechanism controlled by the signal and operable to deenergize the winding of said rapid operator while effecting energization of the winding of the slow operator to cause further expanding pressure to be applied to the honing elements.

8. In a honing machine, the combination of, an expandible honing tool having abrasive elements engageable with the wall of a work bore, a head supporting said tool, means for relatively reciprocating said head and a workpiece to carry the tool into and out of a work bore to be honed, a driving connection including a member connected to said elements and mounted on said head for movement back and forth relative thereto to expand and contract

said hone, fast and slow rotary power operators, means for differentially combining the motions of said operators and applying the resultant motion to said driving connection, said connection including an element normally urged into a held position but movable out of said position in response to the building up of a predetermined torque in the connection following engagement of the honing elements with said wall of the work bore during expansion of said tool, and mechanism responsive to such yielding movement of said element to disable said rapid operator while causing the operation of the slow operator to effect further expansion of the honing tool.

9. In a honing machine, the combination of, an expandible honing tool having movable abrasive elements, a head supporting said tool, means for relatively reciprocating said head and a workpiece to carry the tool into and out of a work bore to be honed, a driving connection including a member connected to said elements and mounted on said head for movement back and forth relative thereto to expand and contract said hone, fast and slow electric operators having rotary drive elements, reversible coupling means including differential gearing combining the motions of said operators and applying the same to said driving connection to cause rapid expansion of said tool when said rapid operator is energized and slow expansion when the slow operator is energized, a friction brake exerting on the driving element of said fast operator a torque predetermined by the degree of energization of the brake, means operable automatically to energize and disable said brake when said fast operator is deenergized and energized respectively, and selectively operable means for adjusting the torque at which said brake will slip whereby to limit the torque permitted to develop in said connection when said honing tool is being expanded by said slow operator.

10. In a honing machine, the combination of, a honing tool having expandible elements, a head supporting said tool, means for relatively reciprocating said head and a workpiece to carry the tool into and out of a work bore to be honed, a driving connection including a member coupled to said elements and mounted on said head for movement back and forth relative thereto to expand and contract said hone, fast and slow electric operators having rotary drive elements, reversible coupling means for combining the motions of said operators and applying the resultant motion to said driving connection to cause rapid expansion of said tool when said rapid operator is energized and slow expansion when the slow operator is energized, a friction brake exerting on the driving element of said fast operator a torque predetermined by the degree of energization of the brake, and selectively operable means for adjusting the torque at which said brake will slip whereby to limit the torque permitted to develop in said connection when said slow operator is active.

11. In a honing machine, the combination of, a rotary honing tool having a plurality of stones and a power actuated member coupled to the stones and movable back and forth to expand and contract the stones, a reciprocable power actuated head supporting said tool, mechanism controlling the actuators for said head and said member to define an automatic cycle comprising advance of the tool into a work bore, expansion and collapse of the tool, reciprocation of the expanded tool in the bore, and withdrawal of the collapsed tool to a predetermined position beyond one end of the bore, a guide ring positioned for engagement with the collapsed tool when the latter is in said withdrawn position, means for sensing the wearing down of said stones to a predetermined point, and mechanism controlled by said sensing means and operable automatically to alter said cycle and cause the actuator for said head to withdraw said tool from the work bore an additional distance and to a position out of engagement with said guide ring following wearing out of said stones.

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12. In a honing machine, the combination of, an expansible honing tool having movable abrasive elements, a reciprocable head supporting said tool, power actuators coupled to said elements and said head for expanding said tool and reciprocating said head, mechanism controlling said actuators to define successive honing cycles each comprising advance of the tool into a work bore, expansion and collapse of the tool, reciprocation of the expanded tool within the bore, and withdrawal of the collapsed tool from the bore, means including a timer rendered active in response to initiation of the collapse of said tool in each of said cycles and adapted to measure a predetermined time interval following such activation, said interval being substantially shorter than the time required for full collapse of said tool, and mechanism controlled by said timer and operable at the end of said interval to interrupt the collapse of said hone by its power actuator.

13. In a honing machine, the combination of, an expansible honing tool having movable abrasive elements, a reciprocable head supporting said tool, power actuators coupled to said elements and head for expanding said tool and reciprocating said head, mechanism controlling said actuators to define successive honing cycles each comprising advance of the tool into a work bore, expansion and collapse of the tool, reciprocation of the expanded tool within the bore, and withdrawal of the collapsed tool from the bore, and means associated with said control mechanism and operating in each of said cycles to limit the duration of operation of the hone actuator in collapsing the tool to a predetermined interval shorter than the interval required for full collapse of the hone, said last mentioned means including a timer started in operation coincident with the initiation of the hone collapse.

14. In a honing machine, the combination of, an expansible honing tool having a plurality of abrading elements, a head supporting said tool and reciprocable to carry the latter into and out of a work bore to be honed, means including a member coupled to said elements and mounted on said head for movement back and forth to expand and permit contraction of said hone, separate high and low speed power operators each having an electromagnetic winding adapted when energized and deenergized to render its associated power operator active and inactive respectively, drive mechanism for transmitting the motions of the respective operators to said member at rapid and slow rates, means operable during expansion of said tool by said rapid operator in the expanding direction to signal actual engagement of said honing elements with the wall of said bore under a predetermined pressure, and mechanism controlled by said signal and operable to deenergize the winding of said rapid operator while energizing the winding of the slow operator to cause the expanding pressure exerted on said abrading elements to be increased.

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