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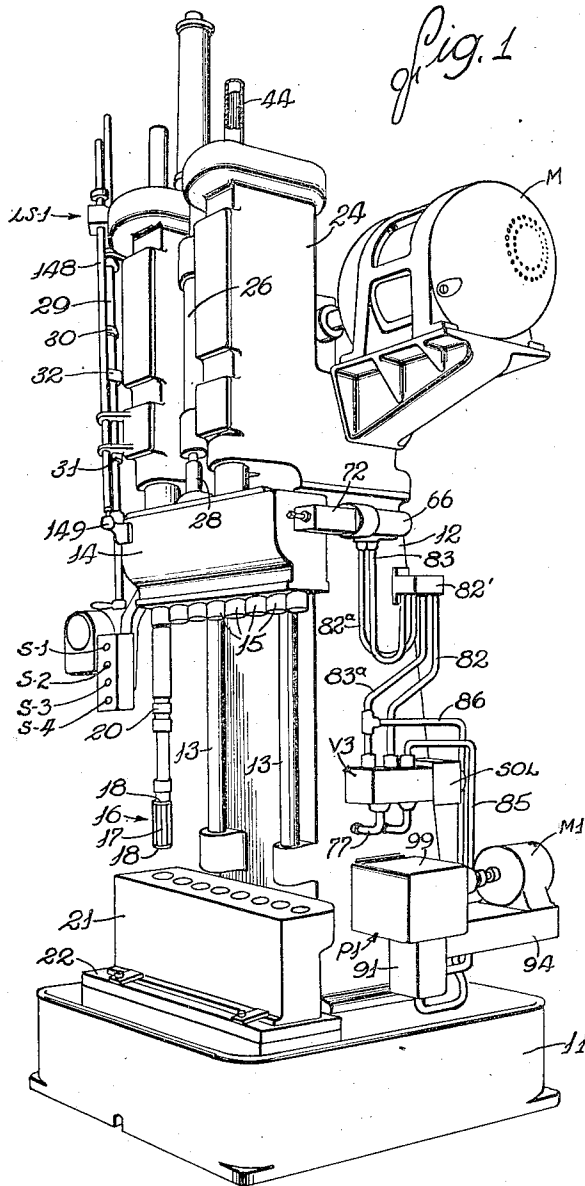
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2,294,184

HONING MACHINE

Filed Feb. 28, 1940

5 Sheets-Sheet 1



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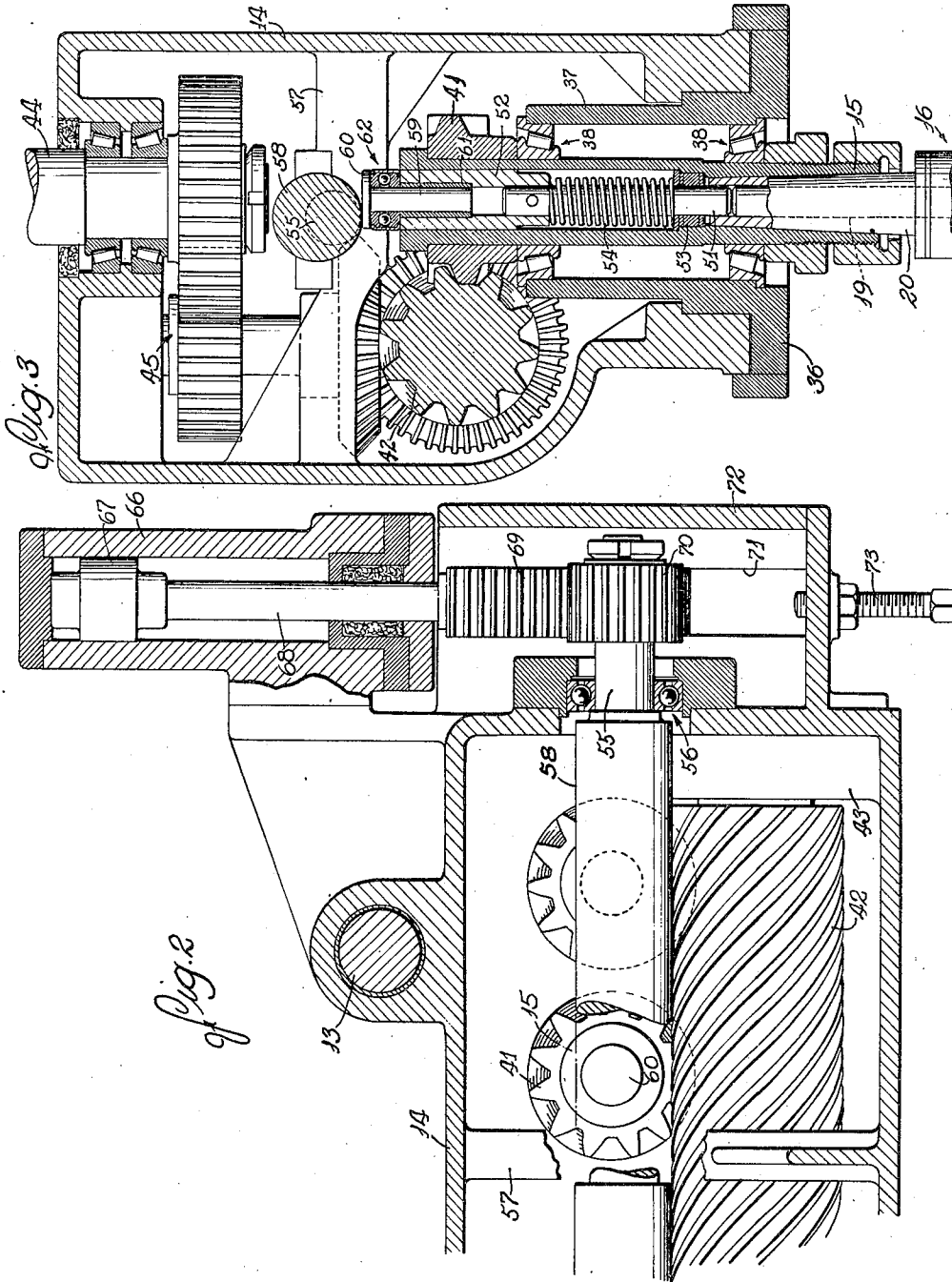
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HONING MACHINE

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5 Sheets-Sheet 2



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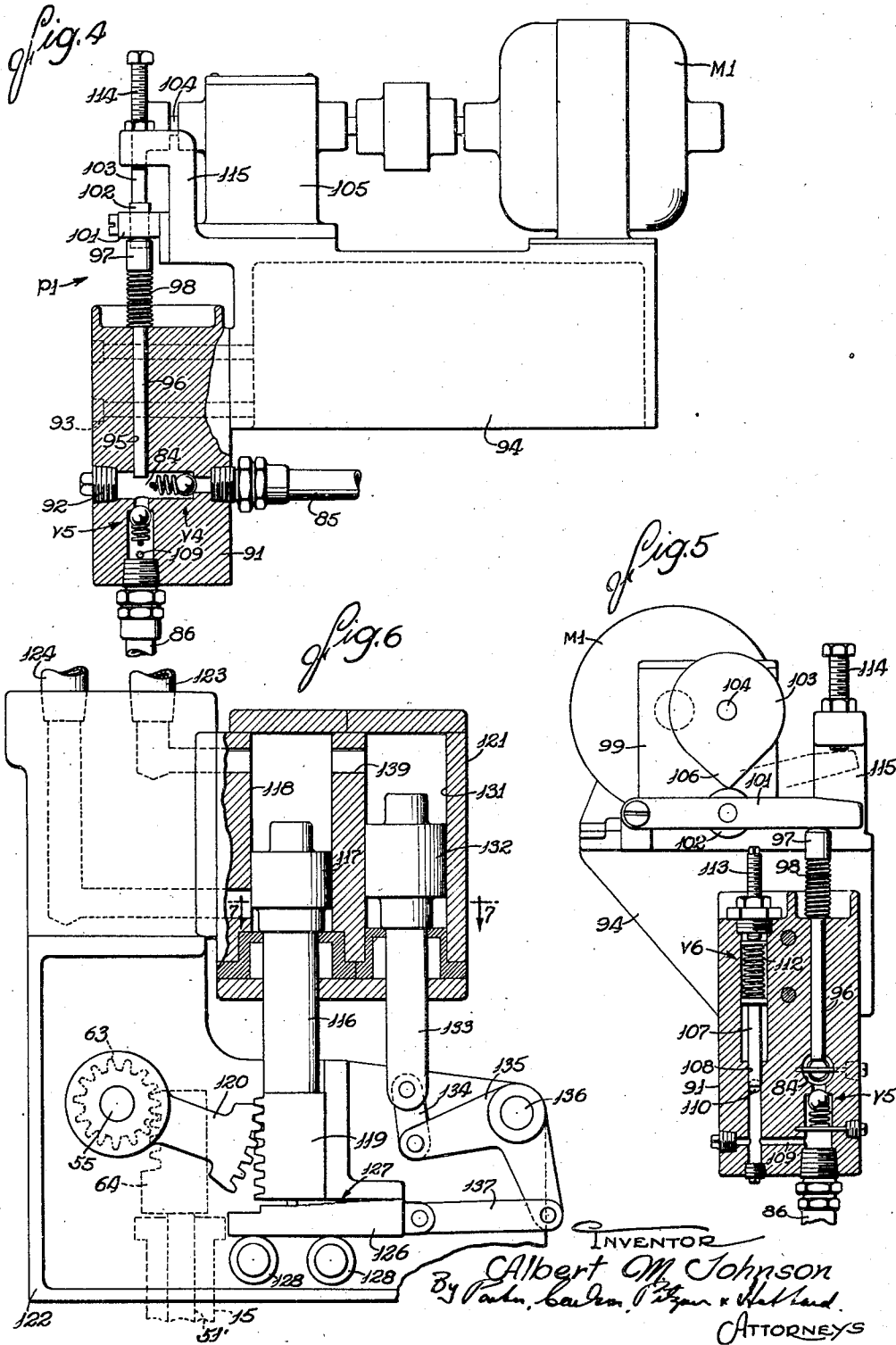
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HONING MACHINE

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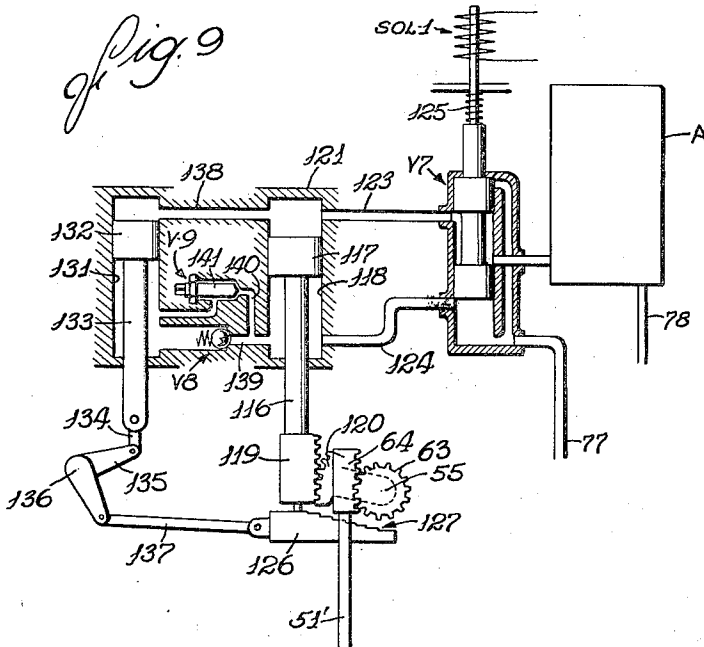
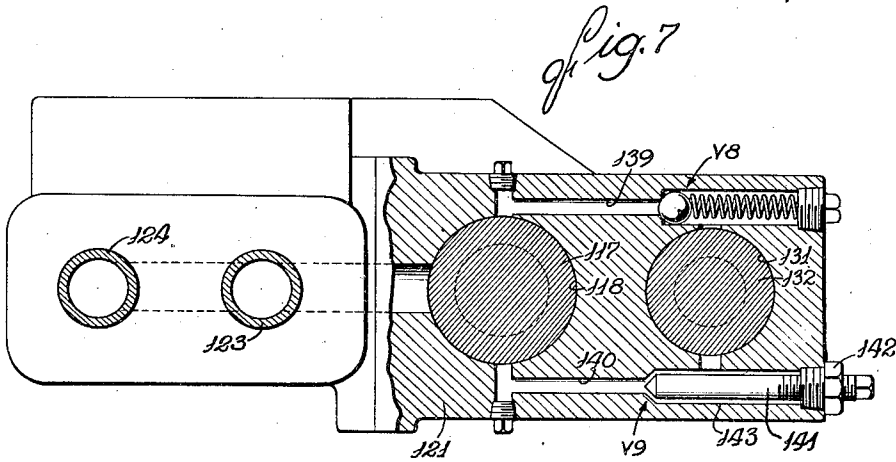
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HONING MACHINE

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5 Sheets-Sheet 4



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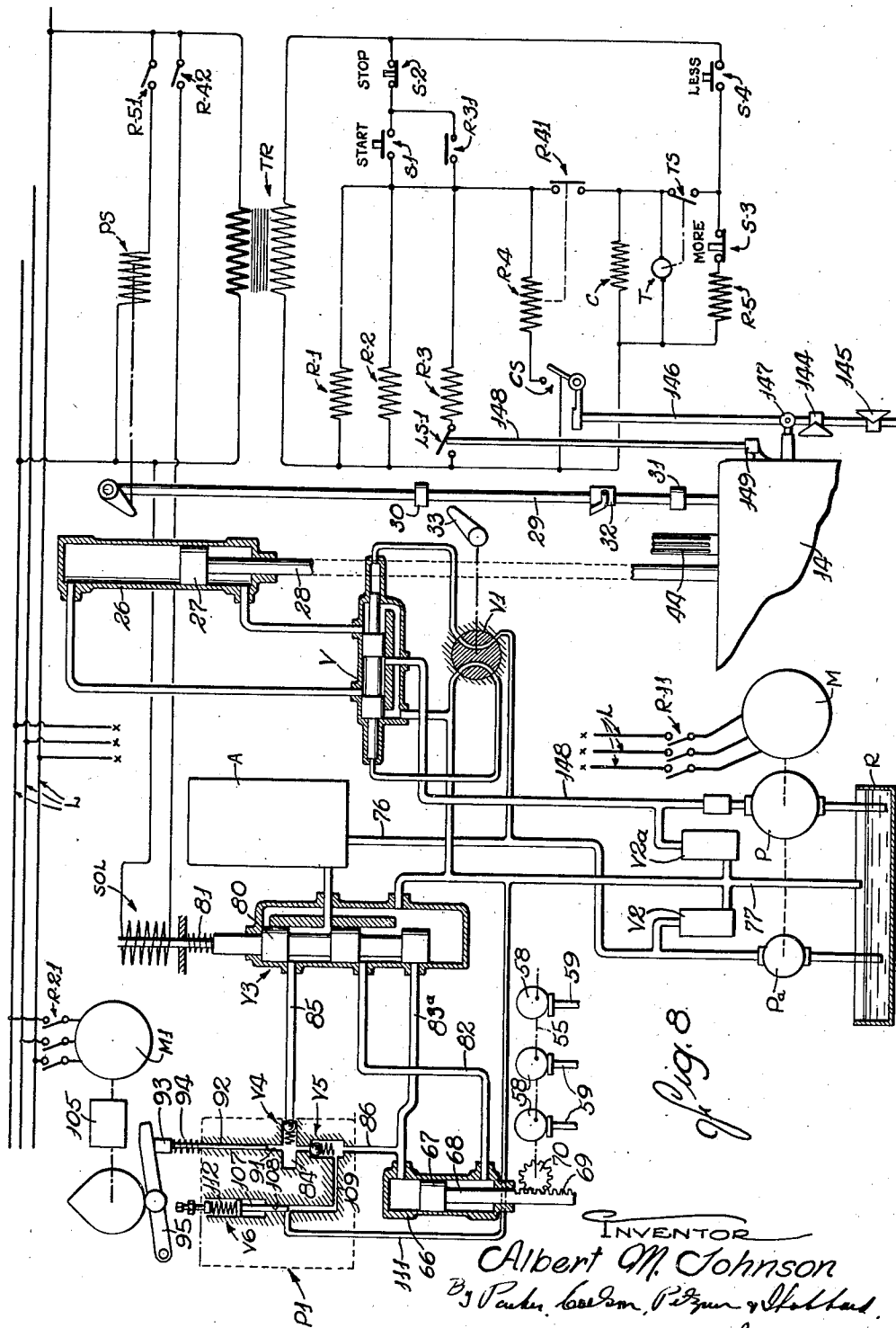
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HONING MACHINE

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5 Sheets-Sheet 5



UNITED STATES PATENT OFFICE

2,294,184

HONING MACHINE

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Application February 28, 1940, Serial No. 321,152

10 Claims. (Cl. 51—34)

The invention relates to machines for dressing cylindrical surfaces and more particularly to improvements in honing or lapping machines.

Machines of the above general character are used extensively in dressing cylindrical work where a true and accurate contour and an extremely smooth surface finish is required. The dressing operation consists of relatively rotating and simultaneously relatively reciprocating the work and an expansible and contractible cylindrical abrasive tool or hone. When the relative rotation of the tool and work is continuous, the operation is commonly known as "honing" and when rotation is intermittent, it is known as "lapping." The term "honing" as employed hereinafter is intended to embrace both methods of operation.

Honing is essentially an abrading operation and efficient action of the tool is dependent largely upon the pressure with which the abrasive elements thereof are forced against the work. Optimum working pressure is determined by a number of factors of which one of the most important is the character of the surface to be dressed. Thus, at the beginning of an operation, while the surface is comparatively rough, it is desirable to press the abrasive stones against the work with relatively light pressure to avoid subjecting the elements to excessive strains. As the surface irregularities are reduced, the pressure may be increased without danger of harming the abrasive elements and in fact should be increased substantially to maintain the operating efficiency of the tool at a maximum.

Various mechanisms have been proposed heretofore for effecting an intermittent positive expansion of the tool in timed relation to its reciprocation. In practice, however, these mechanisms have been unsatisfactory due largely to the extreme difficulty of properly coordinating the tool expansion with the rate at which the metal is removed from the work. Thus, if the tool is expanded more rapidly than the surface of the work is reduced, the abrasive stones are subjected to excessive pressure as well as destructive strains which materially reduce the useful life of the elements and seriously affect the finish produced on the work. On the other hand, if the rate of tool expansion is too slow, the efficiency of the machine is greatly reduced with a resultant increase in production costs.

The present invention aims to overcome the difficulties heretofore encountered by providing improved tool expanding mechanism operative to progressively increase the pressure of the tool

on the work at a rate readily adjustable to enable the tool to operate with maximum efficiency throughout the honing cycle.

Another object is to provide novel means for supplying accurately regulated impulses of pressure fluid to a pressure fluid operated tool expanding mechanism of a honing machine of the like.

Still another object is to provide improved means for expanding a plurality of honing tools simultaneously.

Other objects and advantages of the invention will become apparent from the following detailed description of the preferred embodiments illustrated in the accompanying drawings in which:

Figure 1 is a perspective view of a honing machine embodying the features of the invention.

Fig. 2 is a fragmentary horizontal sectional view of the reciprocatory head of the machine showing details of the spindle driving and tool expanding mechanisms.

Fig. 3 is a transverse vertical sectional view of the head shown in Fig. 2.

Fig. 4 is a side elevational view of the booster pump and associated apparatus for supplying impulses of pressure fluid to the tool expanding means, the pump being shown in section.

Fig. 5 is an end elevational view of the booster pump mechanism shown in Fig. 4.

Fig. 6 is a vertical sectional view of a modified form of tool expanding mechanism.

Fig. 7 is a partially sectioned top view of the tool expanding mechanism shown in Fig. 6.

Fig. 8 is a diagrammatic view showing the electrical and hydraulic circuits and their relationship to the operating elements of the machine.

Fig. 9 is a fragmentary diagrammatic view of the hydraulic circuit as modified for use with the tool expanding mechanism shown in Figs. 6 and 7.

While the invention has been illustrated and will be described hereinafter as embodied in a vertical multiple spindle honing machine of the type in which the tools are rotated and reciprocated relative to stationarily supported work pieces, it is to be understood that it may be incorporated in other types of honing and lapping machines. It is also to be understood that various changes and modifications may be made in the form, construction and arrangement of the parts without departing from the spirit and scope of the invention as expressed in the appended claims.

Referring now to Fig. 1 of the drawings, the machine selected to illustrate the invention comprises generally a rigid base 11 from which rises an upright frame or column 12. Spaced parallel guide bars 13 rigidly mounted on the face of the frame constitute a guideway for a reciprocatory head 14 which, in this instance, is equipped with a plurality of vertically disposed spindles 15 each adapted to carry on its lower end a honing tool 16. Such tools are well known in the art and include a series of abrasive elements or stones 17 arranged around the periphery of a cylindrical carrier for movement radially thereof. The stones are normally held in their inner or contracted position by means of annular springs 18 and are shifted outwardly or expanded by means of an adjusting rod 19 (Fig. 3) extending axially through the hollow shank 20 of the tool.

A work piece 21 to be operated on by the tools, is held in a suitable fixture 22 mounted on the front portion of the base 11 which thus constitutes the work support of the machine. The particular work piece illustrated comprises a conventional motor block having a plurality of parallel cylinders the surfaces of which are to be dressed. It will be understood, of course, that external surfaces may be dressed in a similar operation by using an appropriate form of honing tool.

As indicated above, relative reciprocation of the tool and work is effected in the exemplary machine by reciprocating the tool support or head 14. The head reciprocating means as herein shown, is of the well known pressure fluid operated type including a vertically disposed cylinder 26 (Figs. 1 and 8) having a working piston 27 operatively connected with the head by a piston rod 28. Pressure fluid is supplied to the cylinder by a pump P preferably of the high volume, high pressure type through a hydraulic circuit in which is interposed a reversing valve V of suitable and well known construction. A low pressure pump P_a supplies pressure fluid for operating the valve V and other auxiliaries as will appear presently.

As herein shown, the supply of pressure fluid for operating the valve V is controlled by a pilot valve V-1 actuated in well known manner by the head in its reciprocation through the medium of a control rod 29 arranged to rock about its longitudinal axis and to reciprocate with the head. Mounted on the control rod is a series of stops including upper and lower limit stops 30 and 31 and an intermediate stop 32 arranged to cooperate with an operating lever 33 operatively connected with the movable member of the pilot valve. The stops 30 and 32 define the limits of the working stroke of the head while the stop 31 defines the upper limit of the withdrawal stroke in which the tool is withdrawn from the work.

Referring now to Fig. 3, the head 14 is constructed in the form of a generally rectangular hollow casing having a removable bottom plate 36 provided with a series of integrally formed hollow cylindrical extensions 37 on its inner face. These extensions are arranged in a straight line longitudinally of the head and the spindles 15 are supported therein on antifriction bearings 38 suitably spaced apart to provide the necessary rigidity. The spindles may thus be driven to effect the relative rotation of the tool and work required in the honing operation.

Keyed to the upper end of each spindle 15 is

a helical gear 41 meshing with an elongated helical pinion 42 extending longitudinally of the head and journaled in suitable bearings 43 carried on the end walls of the head. The pinion 42 is arranged to be driven in well known manner by the motor M (Figs. 1 and 8) through the medium of a solenoid actuated clutch C (Fig. 8), a splined drive shaft 44 (Figs. 1 and 3) and a suitable gear train 45 (Fig. 3) enclosed in the head. As will be seen by reference to Fig. 3, the pinion 42 is disposed at one side of the head, thus leaving the inner ends of the spindles unobstructed for installation of the tool expanding mechanism.

The spindles 15 as herein shown, are constructed with a particular view of accommodating power expanded honing tools of the type hereinbefore referred to. To this end the spindles are of tubular form as shown in Fig. 3. Extending axially through each spindle is a tool actuator herein shown as a cylindrical rod 51 having its lower end abutting against the tool adjusting rod 19 and anchored at its upper end in a tubular plunger 52 slidably fitting into the upper end of the spindle. The rod is guided adjacent its lower end in a bushing 53 set in a counterbore within the spindle. A coiled compression spring 54 interposed between the bushing and the lower end of the plunger 52 yieldably urges the rod and plunger upwardly or away from the tool actuating rod 19. With the actuator in its upper position the tool is permitted to contract under the influence of the springs 18.

Suitable power actuated means is provided for shifting all of the actuators simultaneously to expand the associated tools. In the preferred form shown in Figs. 2 and 3, the tool expanding means includes a shaft 55 extending longitudinally of the head above the several spindles 15. The shaft is preferably journaled in antifriction bearings 56 carried on the end walls of the head and on transverse webs 57 extending between the side walls of the head, the number of such webs depending upon the over-all length of the head.

To provide an operative connection between the shaft and the actuators, the shaft is provided with an eccentric cam element 58 extending over each spindle. Cooperating with the cam is a pin 59 having a head 60 interposed in the path of the cam, the shank of the pin being rotatably supported in a bushing 61 set in the upper end of the plunger 52. An antifriction bearing 62 interposed between the upper end of the plunger and the head of the pin takes up the thrust of the cam and permits the pin to remain stationary while the plunger rotates with the spindle. This eliminates unnecessary wear on the heads 60 and cam element 58.

The cam element 58 is so formed that when the shaft is in the normal position shown in Fig. 3, each plunger occupies its uppermost position wherein the abrasive elements of the tool are contracted. When the shaft is rocked out of normal position, the cam element engages the heads 60 and forces the plungers 52 downwardly, thus expanding the tools. Upon return of the shaft to its normal position, the springs 54 return the plungers to their normal position to contract the tools.

In the modified form shown in Fig. 6, the operative connection between the shaft 55 and the various tool actuators is provided by a series of pinions 63 fixed to the shaft in line with each

spindle. The actuator rods 51' (corresponding to the rods 51 hereinbefore described) are, in this instance, extended beyond the upper ends of the spindles and each is provided on its projecting end with a rack 64 meshing with the associated pinion 63. The rod 51' is suitably guided for axial movement and the spindle is rotatable relative to the rod. No restoring spring (such as spring 54) is required for the actuator rod as the movements of the shaft 55 in either direction are transmitted positively by the rack and pinion connections.

Any suitable means may be employed for rocking the tool actuating shaft 55 for expanding and contracting the tools. It is preferred, however, to utilize pressure fluid operated means for this purpose because of its compactness, reliability of operation and ease of adjustment. A preferred form of pressure fluid operated means is shown in Figs. 1 and 2 as comprising a cylinder 66 having a working piston 67, provided with a piston rod 68 terminating at its outer end in a rack 69 meshing with a pinion 70 fast on the outer end of the actuator shaft 55. In the particular form illustrated, the rack is guided in a slideway 71 defined by the side walls of a generally rectangular casing 72 rigidly secured to one end of the head 14.

The arrangement of the cylinder and piston mechanism is such that the shaft 55 is in the normal position shown in Fig. 2 when the piston 67 is at the outer end of the cylinder. In this position of the shaft, the actuators are withdrawn and the tools are contracted. Upon introduction of pressure fluid into the outer end of the cylinder, the piston 67 is moved forwardly, thus rocking the shaft about its axis and causing the cam 58 to shift the actuators and thus expand the tools. The extent of this movement is determined by an adjustable stop herein shown as a screw 73 threaded into the end wall of the casing 72 and having its inner end disposed in the path of the rack 69. Thus, by simply turning the stop screw, the limit position of the rack and the associated tool actuating instrumentalities can be regulated with a high degree of accuracy.

In some instances, as where a plurality of tools of large diameter are employed, it may be desirable to provide two or more pressure fluid operated mechanisms for effecting tool expansion. In such cases, the shaft 55 is conveniently constructed in separate sections, each provided with cylinder and piston actuating mechanism such as that above described.

Pressure fluid may be supplied to the cylinders 66 in any suitable manner. The present invention, however, provides novel pressure fluid circuits and apparatus for this purpose whereby expansion of the tools into relatively light engagement with the work is effected quickly and thereafter as the honing cycle proceeds, the tools are expanded in incremental steps under control of suitable power actuated timing means. The arrangement is preferably such that the pressure exerted by the tools on the work is increased progressively as required for maximum operating efficiency.

Pressure fluid for effecting the initial expansion of the tools may be conveniently derived from the pump P, which supplies pressure fluid for operating the valve V. As above explained, the pump ordinarily used for this purpose is of the type adapted to supply a small volume of fluid at relatively low pressure. The pump as shown in Fig. 8, draws fluid from a sump or reservoir R and dis-

charges it under pressure to a duct 76, the pressure of this fluid being controlled by an adjustable relief valve V2 which opens automatically when the pressure exceeds a predetermined value and returns excess fluid to the sump by way of a drain duct 77.

In order to insure an adequate supply of pressure fluid to effect quick expansion of the tools, a substantial amount of fluid under pressure is stored in an accumulator A (Fig. 8) of suitable and well known construction to which the pressure duct 76 is connected. The flow of pressure fluid from the accumulator to the cylinder 66 is controlled in this instance by a direction control valve V—3 having a plunger 80 yieldably held in a retracted position by a coiled compression spring 81 and adapted to be shifted to an operated position by a solenoid SOL. The plunger 80 when in normal retracted position, directs pressure fluid from the accumulator to the inner end of the cylinder 66 through a duct including a pipe 82, a header 82' (Fig. 1) and a flexible tube 82a. The fluid shifts the piston 67 toward the outer end of the cylinder thereby turning the shaft 55 in a direction to contract the tools. At the same time the outer end of the cylinder is connected with the drain 77 so that the spent pressure fluid from the outer end of the cylinder may be returned to the sump. This connection includes a flexible tube 83, the header 82' and a pipe 83a between the header and the valve.

To expand the tools, the valve plunger is shifted to its operated position in which it directs the pressure fluid from the accumulator to the outer end of the cylinder 66 and connects the inner end of the cylinder to the drain duct 77 for returning spent pressure fluid to the sump. The pressure fluid circuit as shown in Fig. 8 includes a chamber 84 communicating with a booster pump P—1 which gradually increases the pressure of the fluid in the cylinder and therefore the pressure exerted by the tools on the work following the initial expansion of the tools by the pressure fluid supplied from the accumulator. To this end, one duct 85 extends from the valve V—3 to the chamber while another duct 86 extends to the chamber and joins the duct 83a connected to the outer end of the cylinder. Check valves V—4 and V—5 herein shown as valves of the spring pressed ball type, are installed at the incoming and outgoing ports of the chamber 84 to prevent reverse flow of pressure fluid when the booster pump is operating as will be explained presently.

While the booster pump P—1 may be of any suitable type, it is preferred to employ a pulsator pump of the cylinder and piston type capable of delivering impulses of fluid at a pressure substantially higher than the pressure of the fluid supplied from the accumulator. The preferred form of pump shown in Figs. 4 and 5 comprises a casing 91 in the form of a metal block having a transverse bore closed at one end as by a plug 92 to form the chamber 84 previously referred to. As herein shown, the casing is removably secured by screws 93 to one end of a bracket 94 which, in turn, is secured to the side of the machine frame 12 as shown in Fig. 1.

The pump cylinder as herein shown comprises a vertical bore 95 in the casing 91 opening at its lower end into the chamber 84. Slidable within the cylinder is a plunger 96 having its outer end projecting above the casing and terminating in an enlarged head 97. A coiled compression spring 98 interposed between the head 97 and the upper end of the casing urges the plunger

outwardly so that pressure fluid supplied from the accumulator may flow into the lower end of the cylinder. When the plunger is moved downwardly, the fluid is forced out of the cylinder and through the check valve V—5 to the tool expanding cylinder 66. Reverse flow of fluid through the duct 85 is prevented by the check valve V—4.

Means is provided for reciprocating the plunger 92 to supply a succession of pressure fluid impulses to the tool expanding cylinder as the honing operation proceeds. The plunger reciprocating means as shown in Figs. 4 and 5 comprises a lever 101 pivoted at one end on the bracket 94 and having its free end positioned to engage the head 97 of the plunger. Mounted intermediate the ends of the lever 101 is a follower roller 102 cooperating with a cam 103 fast on a shaft 104 journaled in a housing 105 mounted on the bracket 94. The shaft is arranged to be driven by an electric motor M—1 through the medium of speed reducing gearing of any suitable and well known type enclosed in the casing 105. The cam 102 as herein shown is formed with a single lobe 106 adapted to depress the lever 101 once in each revolution and thus shift the plunger 96 downwardly against the action of the spring 98. The cam and associated mechanism are protected by enclosure in a suitable housing 99 (Fig. 1) of sheet metal or the like.

Maximum pressure exerted by the tools on the work is determined by a relief valve V—6, preferably of the adjustable type capable of being set as required for the work being done. This valve, as herein shown, comprises a plunger 107 working in a cylinder 108 formed by a bore in the block 91. The cylinder 108 communicates at its lower end through a passage 109 with the pressure duct 86 and the plunger when forced upwardly by the pressure fluid introduced through the passage uncovers a port 110 in the side wall of the cylinder to by-pass excess fluid through a duct 111 to the drain 77. Movement of the valve plunger is resisted by a compression spring 112 interposed between the upper end of the plunger and the tip of an adjusting screw 113 threaded into a plug in the upper end of the cylinder. The pressure at which the valve opens can thus be regulated by turning the adjusting screw in one direction or the other.

In order to regulate the volume of fluid delivered at each impulse and thus control the rate at which the pressure exerted by the tools on the work is increased, suitable means is provided for varying the stroke of the plunger 96. This means, as herein shown, comprises an adjustable stop in the form of a screw 114 threaded into an L-shaped arm 115 integral with the bracket 94 and overhanging the free end of the lever 101. The lower end of the screw engages the lever 101 and thus determines its upper limit position. Thus, by simply turning the screw in one direction or the other the swing of the lever and therefore the stroke of the plunger may be varied as required. This adjustment is entirely independent of the various machine operations such as reciprocation and rotation of the tool hence, the rate at which the tool pressure is increased can be easily and accurately adjusted to meet the requirements of any particular work.

A modified form of pressure fluid operated mechanism for actuating the tool expanding and contracting shaft 55 is shown in Figs. 6, 7 and 9 as comprising a plunger 116 having at one end a piston 117 working in a cylinder 118 and at its

other end a rack member 119 meshing with a segmental pinion 120 fast on the shaft 55. The cylinder is preferably formed in a generally rectangular metal block or casing 121 carried on the upper end of a flanged bracket 122 adapted to be secured to the head 14 in place of the housing 72 previously described.

Pressure fluid is supplied to the cylinder 118 under control of a reversing valve V—7 (Fig. 9) of conventional construction arranged to connect ducts 123 and 124 communicating with opposite ends of the cylinder to the accumulator A and the drain duct 77 alternately. The arrangement is such that the piston on moving from the outer toward the inner end of the cylinder is effective to rock the shaft 55 in a direction to expand the honing tools with which it is associated. A coiled compression spring 125 yieldably urges the valve to tool contracting position while a solenoid SOL—1 acts, when energized, to operate the valve to its alternate position and initiate expansion of the tools.

In order to control the rate of which the abrasive elements of the tools are fed to the work, suitable means is provided for limiting the inward movement of the plunger 116 to a series of successively executed steps of predetermined length. The limiting means as herein shown comprises a stop member or wedge 126 (Figs. 6 and 9) positioned adjacent the inner end of the plunger. The side of the wedge facing the plunger is formed with a series of stepped surfaces 127 of progressively decreasing height from left to right as viewed in Fig. 9. These surfaces or steps are adapted to be presented in the path of the plunger 116 by shifting of the wedge in the direction of its length. For this purpose the wedge is movably supported on spaced rollers 128 (Fig. 6) journaled on the bracket 122.

In the operation of the mechanism, the highest step of the wedge, that is the step at the extreme left end of the wedge as viewed in Fig. 9, is initially presented for engagement by the plunger, thus imposing a minimum limit upon its inward movement and the consequent expansion of the tool at the beginning of the honing operation. As the honing operation proceeds, the wedge is shifted gradually to present successive lower steps in the path of the plunger which is advanced into engagement with such steps by the continued application of pressure to the outer end of the piston 117. The plunger therefore advances intermittently to rock the shaft 55 and thus progressively increase the pressure exerted by the tools on the work.

While any suitable means may be utilized for withdrawing the wedge in the manner above described, the invention provides a novel pressure fluid operated mechanism for this purpose which is simple and reliable in operation and capable of being regulated with a high degree of accuracy to coordinate the rate of tool expansion with the rate at which metal is removed from the surface of the work. The wedge withdrawing mechanism in its preferred form comprises a cylinder 131 conveniently formed by a bore in the block 121 at one side of the cylinder 118. Working in the cylinder 131 is a piston 132 having a piston rod 133 projecting from the cylinder substantially parallel to the plunger 116 and connected to the wedge 126 by a suitable linkage for transmitting movements of the piston thereto. This linkage as herein shown includes a link 134 connecting the outer end of the piston rod with one arm of a bell

crank lever 135 pivoted at 136 on the bracket 122, the other arm of the bell crank being connected with the wedge by a link 137.

As shown in Fig. 9, the cylinders 118 and 131 are connected at their outer and inner ends by passages 138 and 139, the latter being fitted with a spring pressed ball check valve V-8 to permit fluid to flow in one direction only, that is from the cylinder 118 to the cylinder 131. This check valve is by-passed by an auxiliary passage 140 in which is interposed a valve V-9 having a member in the form of an elongated rod 141 (Fig. 7) threaded into a plug 142 closing the end of an enlarged section 143 of the passage 140. The inner end of the member 141 is tapered to coact with a similarly tapered seat formed at the junction of the passage 140 and the section 143 and it thus serves to determine the flow area of the passage. By reason of its threaded engagement with the plug, the valve member is readily adjustable to vary the flow of fluid from the cylinder 131.

With the above arrangement the pistons 117 and 132 are quickly shifted to the outer ends of their respective cylinders, when the direction valve V-7 is set in its normal position to direct pressure fluid to the inner end of the cylinder 118, the pressure fluid immediately passing into the cylinder 131 through the passage 139 and check valve V-8. The first mentioned piston effects contraction of the tools and the latter advances the wedge 126 to present its highest step in the path of the plunger 116.

Upon operation of the valve V-7 to its alternate position, pressure fluid is directed into the outer ends of the cylinders 118 and 131 to shift the pistons in the opposite direction. The piston 117 advances rapidly until its movement is interrupted by engagement of the plunger with the highest step of the wedge 126. The piston 132 on the other hand, advances slowly since the pressure fluid must be exhausted from the inner end of the cylinder through the restricted passage provided by the valve V-9, the valve V-8 effectively blocking the passage 139 under these conditions. Accordingly, the wedge 126 is withdrawn relatively slowly to present the successive steps in the path of the plunger 116 which accordingly advances progressively as each succeeding step is positioned in line with the plunger. The rate of plunger advance can be accurately controlled by adjusting the position of the valve member 141. As this adjustment is entirely independent of any operation functions of the machine, the rate of tool expansion, or in other words, the rate at which the pressure of the tools is increased can be closely coordinated with their metal removing action to insure maximum operating efficiency.

In placing the machine in operation, the work is secured in place on the work support and the limit stops 30 and 32 are set to define the desired working stroke of the tools. Cams 144 and 145 (Fig. 8) carried on a rocking control rod 146 are positioned so that the latter is engaged by an arm 147 on the head when the tools have been fully inserted in the work. Cam 144 is set for engagement by the arm when the head moves beyond the upper limit of its work stroke but before the tools are withdrawn from the work. Engagement of these cams by the arm serves to rock the shaft 146 about its axis to initiate certain control operations as will appear presently.

After the machine has been preliminarily set

in the above manner, it is started by momentary action of a start switch S-1 which energizes a pair of motor control relays R-1 and R-2. Current is supplied to these relays and to other elements of the control system through a voltage reducing transformer TR connected to a power line L. Relay R-1, when energized, closes its switch R-11 to connect the main driving motor M to the power line L. Relay R-2, when energized, closes switch R-21 to connect the booster pump motor M-1 to the power line L. The motor M drives the pumps P and Pa. The latter supplies pressure fluid to the reversing valve V and the accumulator A. The pump P delivers a supply of pressure fluid to the cylinder 26 by way of a duct 148. A relief valve V2a of well known construction controls the pressure of the fluid. The pressure fluid is directed into the upper end of the cylinder by the valve V which is set in the position shown in Fig. 8 at the start of the operating cycle. The tool head and tools are accordingly moved toward the work.

The start switch is held in closed position until the head is moved out of its normal rest position at which time a holding circuit is completed for the relays R-1 and R-2 by energization of a latch relay R-3 to close a switch R-31. The energizing circuit for the latch relay is completed through a limit switch LS-1 closed in response to the downward movement of the head through the usual stop bar 148 which rests upon a bracket 149 on the head when the latter is in its rest position. The relays R-1 and R-2 accordingly remain energized and continue the operation of the motors M and M-1 until their holding circuit is interrupted either by the opening of the switch R-31 or a manually operable stop switch S-2.

As the head continues its downward movement, the intermediate stop 32 passes the pilot valve actuator 33 without operating the valve and when the tools have been fully entered in the work, the arm 147 engages the cam 145 to rock the control rod 146 and close a switch CS to energize a control relay R-4. This relay closes a switch R-41 to energize the clutch C and thus initiate rotation of the tools. A circuit is completed at the same time for an electrical timer T of any suitable and well known type which has previously been set to determine the length of the working cycle of the machine.

Relay R-4 also closes a switch R-42 to energize the solenoid SOL which operates the valve V-3 to its alternate position, thus directing pressure fluid from the accumulator A into the upper end of the tool expanding cylinder 66. Pressure fluid supplied from the accumulator quickly expands the tools into relatively light engagement with the work so that the major surface irregularities may be removed without subjecting the tools to excessive strains. As the honing operation proceeds the booster pump P-1 supplies successive impulses of pressure fluid to the cylinder 66 to progressively increase the pressure exerted by the tools on the work so that they may function at maximum efficiency throughout the honing cycle.

During the honing cycle the tools are traversed repeatedly from one end of the work to the other under control of the limit stops 30 and 32 which in well known manner actuate the pilot valve V-1 to shift the direction valve V between its alternate positions. At the end of the honing cycle as determined by the timer T, the latter closes its switch TS to complete an energizing circuit

for a control relay R—5. This relay closes switch R—51 to energize a pull-out solenoid PS which in well known manner rocks the control rod 29 about its longitudinal axis to move the intermediate stop 32 to a position in which it is ineffective to engage the pilot valve actuating arm 33. The next upward stroke of the head therefore is continued beyond the upper limit of the working stroke until the head reaches its limit position as determined by the upper limit stop 31. When desired, the length of the operating cycle may be increased by actuation of a manually operable push button switch S—3 connected in series with the timing switch TS. A cycle may be terminated at any time, of course, independently of the timer by closing a manually operable switch S—4.

Before the tools are withdrawn from the work the arm 147 engages the cam 144 and rocks the control rod 146 to open the switch CS and thus deenergize relay R—4. This relay, by opening switch R—41 deenergizes the clutch C to interrupt the rotation of the tools and by opening switch R—42 deenergizes solenoid SOL to return the valve V—3 to its normal position. The valve directs pressure fluid from the accumulator into the inner end of the cylinder 66, thus quickly contracting the tools.

As the head approaches its upper limit position, limit switch LS—1 is opened to interrupt the circuit for the latch relay R—3 and this relay opens the holding switch R—31 to deenergize the motor control relays R—1 and R—2. The machine is therefore brought to a complete stop with the various control elements in the position shown in Fig. 8 and in readiness for the start of the next operating cycle.

It will be apparent from the foregoing that the invention provides a honing machine of novel and advantageous character. The machine embodies novel means for expanding a plurality of honing tools simultaneously together with actuating means effective to progressively increase the pressure exerted by the tools on the work as the honing operation progresses. The tool expanding means is readily adjustable so that tool pressure may be accurately coordinated with the metal removing actions of the tools and thus enable the tools to operate at maximum efficiency at all times.

I claim as my invention:

1. A honing machine having, in combination, a reciprocatory head, a plurality of hollow tool spindles each journaled at one end on said head and adapted to carry on the other end an expansible and contractible honing tool, an actuator for each honing tool including a member slidable axially of the spindle and projecting into the head, means yieldably holding said members in a withdrawn position with the honing tools contracted; means for shifting said members simultaneously to an operated position to expand the tools, said shifting means including a shaft journaled in the head and in the head and extending transversely across the same adjacent the inner ends of the spindle, means providing an operative connection between the shaft and each of the actuator members effective when the shaft is rocked in one direction to expand the tools, a rack slidably mounted in the head for movement transversely of said shaft, a pinion fast on said shaft meshing with said rack, and power operated means for driving said rack.

2. A honing machine having, in combination, a reciprocatory head, a plurality of tool spindles

each journaled at one end in said head and adapted to carry on the other end an expansible and contractible honing tool, an actuator for each tool including a member extending into the head, spring means yieldably holding the actuators in a withdrawn position to permit the tools to contract, means for shifting the actuators simultaneously to an operated position to expand the tools, said shifting means including a shaft journaled in the head and extending transversely across the same above the tool spindles, means providing an operative connection between said shaft and each of said actuators, a pinion fast on said shaft, a plunger supported for endwise movement transversely of the shaft having a rack portion engaging said pinion, a piston at one end of said plunger, a cylinder for said piston, and means for supplying pressure fluid to said cylinder to move the plunger in either direction and thereby rock the actuator shifting shaft between active and inactive positions.

3. A honing machine having, in combination, a reciprocatory head, a plurality of tool spindles each journaled at one end in said head and adapted to carry on the other end an expansible and contractible honing tool, an actuator for each tool including a member extending into the head, means yieldably holding the actuators in a withdrawn position to permit the tools to contract, means for shifting the actuators simultaneously to an operated position to expand the tools, said shifting means including a shaft journaled in the head and extending transversely across the same above the tool spindles, cam means on said shaft engaging each of said actuators, a pinion fast on said shaft, a rack cooperating with said pinion, and power operated means for driving said rack.

4. A honing machine having, in combination, a reciprocatory head, a plurality of hollow tool spindles each journaled at one end in said head and adapted to carry on the other end an expansible and contractible honing tool, a tool actuator extending from each tool through its associated spindle and into the head, means yieldably holding the actuators in a withdrawn position to permit the tools to contract, means for shifting the actuators simultaneously to an operated position to expand the tools, said shifting means including a shaft journaled in the head and extending transversely across the same above the tool spindles and in axial alignment therewith, cam means on said shaft engaging each of said actuators, and power driven means for rocking the shaft.

5. A honing machine having, in combination, a reciprocatory head, a plurality of hollow tool spindles each journaled at one end in said head and adapted to carry on the other end an expansible and contractible honing tool, a tool actuator extending from each tool through its associated spindle and into the head, means yieldably holding the actuators in a withdrawn position to permit the tools to contract, means for shifting the actuators simultaneously to an operated position to expand the tools, said shifting means including a shaft journaled in the head and extending transversely across the same above the tool spindles, a ratchet member fast on the projecting end of each actuator, pinions on said shaft engaging said rack members, and power actuated means for rocking the shaft.

6. A honing machine having, in combination, a support for an expansible and contractible hon-

ing tool, a support for work to be operated on by the tool, means for effecting relative rotation and simultaneous relative reciprocation of the tool and work, pressure fluid actuated means for expanding the tool into operative engagement with the work, a source of fluid maintained substantially at a predetermined pressure, means operative to direct pressure fluid from said source to said tool expanding means to expand the tool into engagement with the work, and means operative to supply successive impulses of fluid at a higher pressure to said tool expanding means to progressively increase the pressure exerted by the tool on the work.

7. A honing machine having, in combination, a support for an expansible and contractible honing tool, a support for work to be operated on by the tool, means for effecting relative rotation and simultaneous relative reciprocation of the tool and work, pressure fluid actuated means for expanding the tool, a pressure fluid accumulator, means for connecting said accumulator to said tool expanding means to rapidly expand the tool into operative engagement with the work, said tool exerting a predetermined pressure on the work, and other means for delivering successive impulses of fluid to said tool expanding means at a higher pressure than the fluid supplied from said accumulator to progressively increase the pressure exerted by the tool on the work.

8. A honing machine having, in combination, a support for an expansible and contractible honing tool, a support for work to be operated on by the tool, means for effecting relative rotation and simultaneous relative reciprocation of the tool and work, pressure fluid actuated means for expanding the tool, a pressure fluid accumulator, a pump for delivering fluid to said accumulator at a predetermined pressure, means for connecting said accumulator to said tool expanding means to effect rapid expansion of the tool into operative engagement with the work, and a booster pump interposed between the accumulator and

said tool expanding means operative to effect a gradual increase in the pressure exerted by the tool on the work.

9. A honing machine having, in combination, a support for an expansible and contractible honing tool, a support for work to be operated on by the tool, means for effecting relative rotation and simultaneous relative reciprocation of the tool and work, a cylinder and piston mechanism for expanding the tool, a pressure fluid pump adapted to deliver a substantial volume of fluid at relatively low pressure, a second pressure fluid pump adapted to deliver a succession of impulses of pressure fluid at a substantially higher pressure, a pressure fluid line extending from said first pump to said second pump, a second pressure fluid line extending from the second pump to the cylinder of said mechanism, and valve means interposed between said lines effective to permit pressure fluid to pass from said first pump to the cylinder to initially expand the tool into engagement with the work, said second pump acting thereafter to supply the pressure fluid to the cylinder in a succession of impulses effective to gradually increase the pressure exerted by the tool on the work.

10. A honing machine having, in combination, a support for an expansible and contractible honing tool, a support for work to be operated on by the tool, power actuated means for effecting relative rotation and simultaneous relative reciprocation of the tool and work, pressure fluid actuated means for expanding and contracting the tool, a source of pressure fluid, a pump, means for supplying pressure fluid from said source to said actuating means and said pump, said actuating means operating initially to expand the tool against the work, and means connecting said pump with said actuating means to deliver successive impulses of pressure fluid from the pump to the actuating means for further expanding the tool in incremental steps.

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