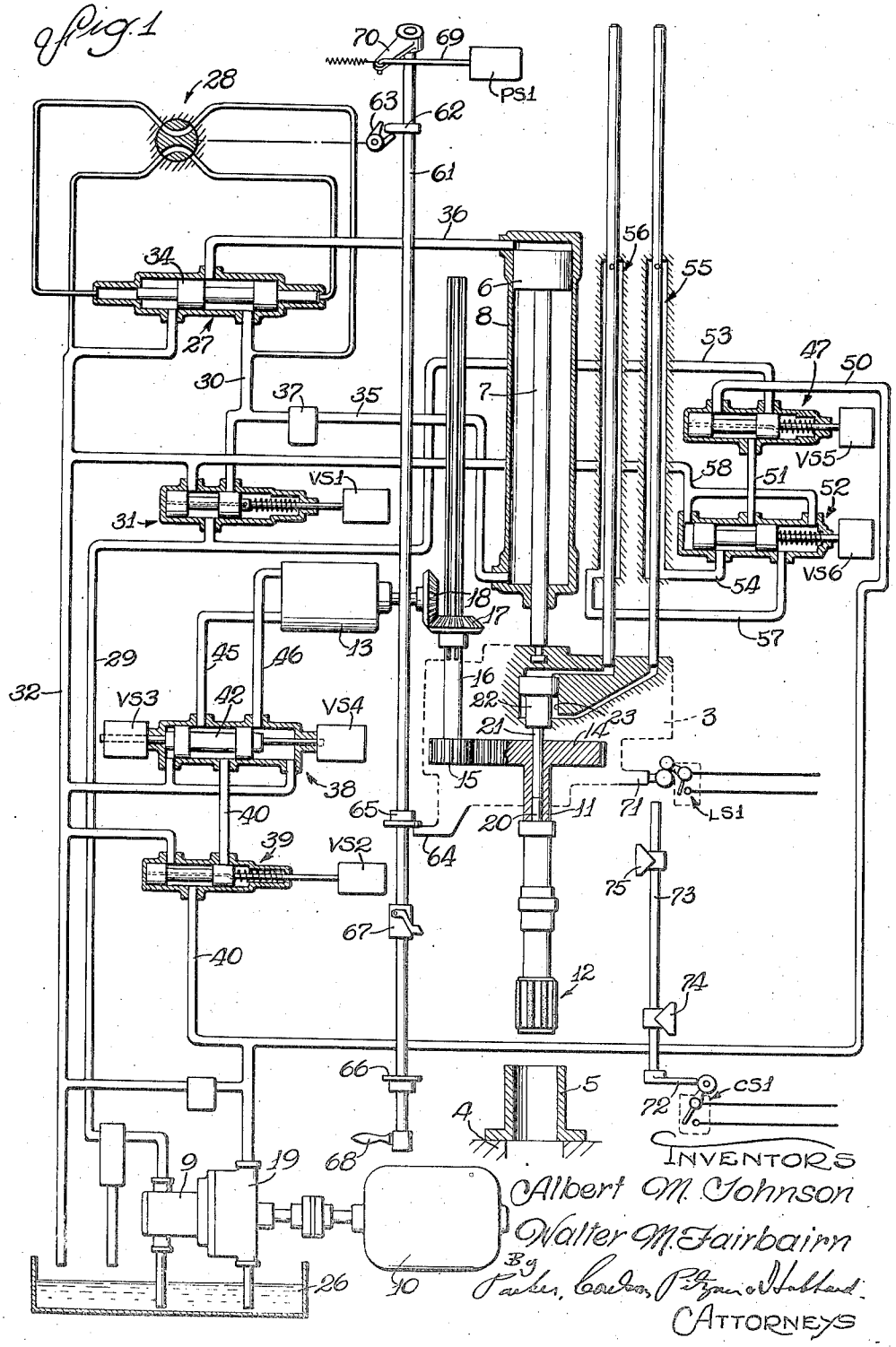
Aug. 1, 1939. A. M. JOHNSON ET AL 2,167,758

METHOD AND MACHINE FOR HONING CYLINDRICAL SURFACES

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Fig. 1

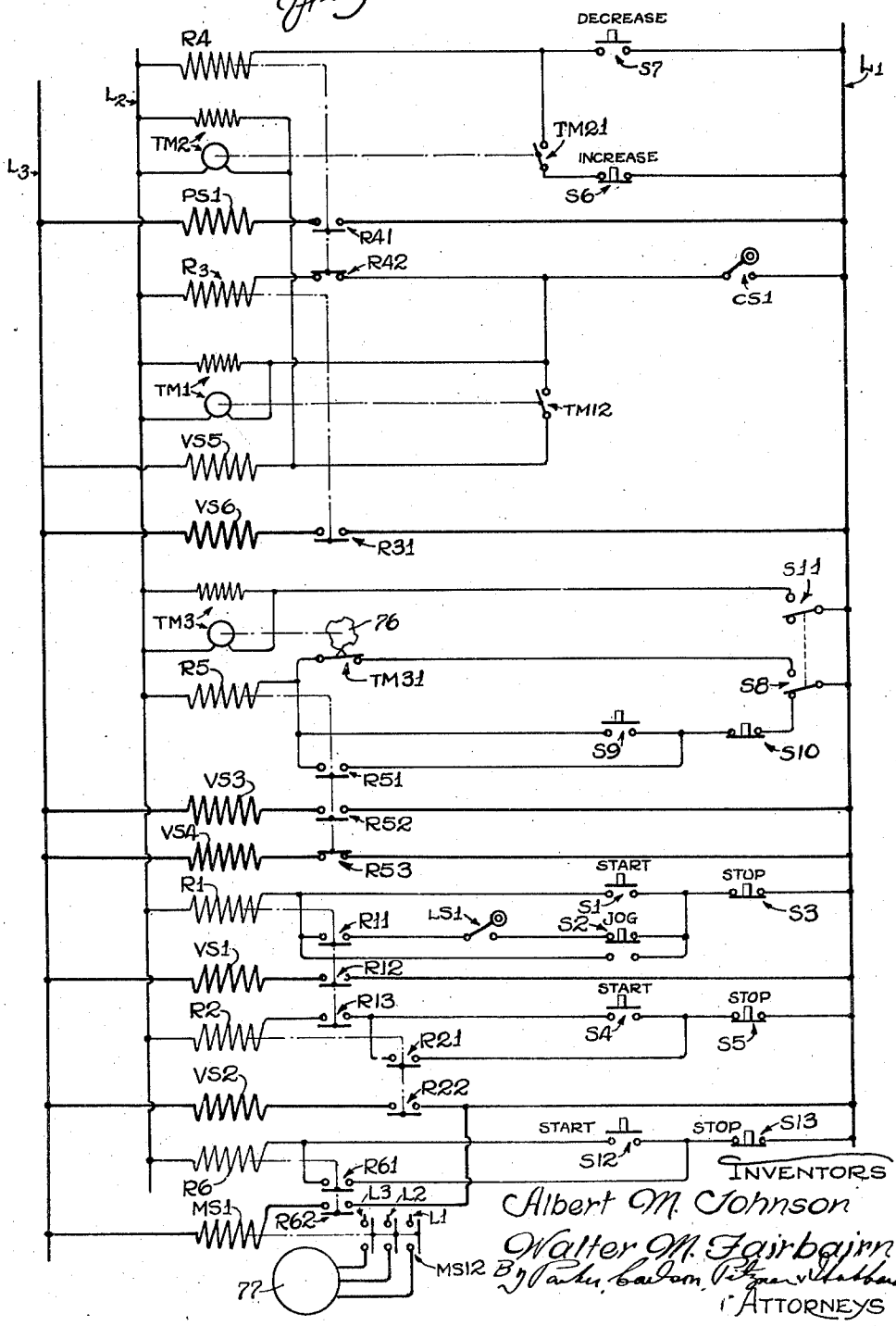


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METHOD AND MACHINE FOR HONING CYLINDRICAL SURFACES

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Fig. 2



INVENTORS
Albert M. Johnson
Walter M. Fairbairn
By Parker, Carlson, Pitzner & Hubbard
ATTORNEYS

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METHOD AND MACHINE FOR HONING CYLINDRICAL SURFACES

Albert M. Johnson and Walter M. Fairbairn, Rockford, Ill., assignors to Barnes Drill Co., Rockford, Ill., a corporation of Illinois

Application March 18, 1938, Serial No. 196,636

18 Claims. (Cl. 51—34)

The invention relates to the art of dressing cylindrical surfaces and more particularly to an improved machine for and method of dressing such surfaces by a honing or lapping operation.

The primary object of the invention is to improve the efficiency of the honing operation, to reduce the amount of power required in the initial stage of the operation, and to increase the useful life of the tools employed in carrying out the operation.

Another object of the invention is to provide a new and improved method of honing cylindrical surfaces in which the removal of irregularities left on the surface by a preliminary boring or grinding operation and the dressing of the surface to a true contour and smooth finish are carried cut in separate steps.

Another object is to provide an improved method of honing cylindrical surfaces in which tool pressure on the surface being dressed is varied in different stages of the honing operation.

Another object is to provide an improved honing machine embodying novel tool-actuating means and controls therefor whereby the honing tool may be actuated in a series of steps in each of which a different degree of pressure is applied to the surface of the work piece by the tool.

Another object is to provide an improved machine adapted for rough and finish honing in which the duration of the different operations is controlled by timing means.

Another object is to provide in a machine of the above general character a novel and efficient arrangement of electrical and hydraulic circuits and controls therefor by which the operation of the machine may be conveniently controlled from a single central station.

Still another object is to provide an improved electrical control system for controlling the operation of a honing machine.

A further object is to provide novel means for reversing the rotation of the honing tool during the honing operation.

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

Figure 1 is a diagrammatic view showing the relationship of the various machine elements and the associated hydraulic-actuating and control means.

Fig. 2 is a schematic diagram showing the electrical circuits and apparatus comprising the improved electrical control system.

The features of the invention may be embodied in various types of machine tools and are particularly suitable for use in machines for dressing cylindrical surfaces by a honing or lapping process in which a cylindrical abrasive tool or hone is rubbed over the surface of the work piece by a combination of movements including relative rotation of the tool and work and relative axial reciprocation of the tool and work. For purposes of illustration, the invention is herein disclosed embodied in a honing machine in which the tool is rotated and reciprocated relative to a stationary work piece. It is to be understood, however, that the invention may be applied to other types of honing and lapping machines and is in nowise limited to the specific form or environment disclosed but embraces all modifications, adaptations and alternative constructions coming within the spirit and scope of the appended claims.

Honing machines have recently become available in which the expansion of the tool is effected hydraulically. For many purposes, these machines represent a distinct improvement over prior machines employing spring-expanded tools since they provide a uniform tool pressure throughout the honing operation, whereas with a spring-expanded tool, the tool pressure is at its maximum at the beginning of the operation and gradually decreases as the diameter of the work increases. In either case, the amount of pressure that can be applied with safety is determined by the ability of the tool to withstand the strain imposed by its initial engagement with the rough surface of the work piece. Accordingly, when the tool is expanded within safe limits of pressure at the beginning of the operation, it necessarily operates below its maximum efficiency after the major irregularities have been removed from the surface with attendant decrease in the resistance offered to the rotation of the tool.

The present invention aims to overcome the foregoing difficulties by providing means of a novel and advantageous character whereby the pressure with which the tool is applied to the surface of the work may be varied as required. Thus, in honing work where the surface is in a very rough condition, the tool may be applied to the surface with a relatively light pressure for an interval sufficient to remove the major irregularities. In this roughing operation, the surface is smoothed off somewhat so that resistance to the tool is decreased substantially. Accordingly, the next step or finishing operation may then be carried out with increased tool pressure to en-

able the tool to continue to operate at maximum efficiency. In this way, high efficiency is obtained without subjecting the tool to undue strains and the useful life of the tool is correspondingly increased.

It may also be desirable at times to reverse the order in which the changes in tool pressure are effected as, for instance, when it is necessary to limit the amount of metal removed in the finishing operation. This can be accomplished readily without change in the machine structure by a simple modification of the controls.

The invention also provides novel means for controlling the duration of the different operating stages automatically. This means comprises suitable timing devices, preferably electrically operated, with appropriate control apparatus whereby each stage is terminated after a predetermined time. The timing devices, of course, are adjustable so that the length of each operating stage may be varied as required for different classes of work.

The operating efficiency of the tool is further increased by the provision of automatic means for periodically reversing the direction of rotation of the tool. In the present instance, this is accomplished by a reversal of the motor which drives the tool. Reversal of the tool tends to prevent "loading" of the abrasive stones and equalizes wear over the entire surface thereof. Moreover, when tool rotation is reversed, a different area of the abrasive stone is presented to the work, thus further increasing the cutting efficiency of the tool.

Control of the machine is effected through the medium of push button switches which may be grouped at a conveniently located central control station. The work of the attendant running the machine is thus materially simplified which facilitates efficient operation.

General machine structure

The machine illustrated in Fig. 1 of the drawings comprises generally a carriage or head 3 mounted on a suitable frame (not shown) for reciprocation toward and from a stationary work supporting fixture 4 which holds the work piece 5 to be operated on. Reciprocation of the head is effected by means of a piston 6 operatively connected with the head by a piston rod 7. The piston is operable in a cylinder 8 mounted on the frame of the machine with its axis substantially parallel to the reciprocatory path of the head. A high pressure pump 9 driven by an electric motor 10 supplies pressure fluid to the cylinder 8 through a hydraulic circuit to be described in detail hereinafter.

Journaled in the head 3 and reciprocable therewith is a hollow spindle 11 which carries on its projecting end a cylindrical honing tool 12 of well known construction. The spindle 11 is arranged to be driven by a reversible motor 13 mounted on the frame of the machine. In the machine illustrated, a rotary hydraulic motor is employed, although it will be understood that an electric motor may be used if desired.

The driving connection between the motor 13 and the spindle 11 includes a gear 14 rigid with the spindle which meshes with a pinion 15 fast on a drive shaft 16 adapted to reciprocate with the head. The shaft 16 has a splined driving connection with a beveled gear 17 journaled on the frame of the machine, which gear meshes with a beveled gear 18 on the shaft of the motor 13. Pressure fluid for operating the motor 13 is supplied by a low pressure pump 19 driven by the electric motor 10.

The honing tool 12 is preferably of the general type disclosed in the copending application of A. M. Johnson, Serial No. 174,955. It comprises generally a plurality of abrasive elements arranged in a circular series in a cylindrical frame for radial movement into and out of engagement with the surface of the work. For dressing internal cylindrical surfaces, the abrasive elements are arranged to face outwardly, their positions being reversed for honing external cylindrical surfaces. With either type of tool, movement of the abrasive elements into engagement with the work is commonly referred to as "expanding" the tool while retraction of the elements is referred to as "contracting" the tool. The terms are used with the above significance in the present specification and claims.

Expansion and contraction of the tool is effected by suitable tool-actuating means preferably adapted to be operated hydraulically. The actuating means as herein shown includes an endwise shiftable rod 20 extending axially of the tool. When the tool is secured to the hollow spindle 11, the rod 20 projects into the axial bore of the spindle for engagement by a push rod 21 operatively connected with a piston 22 working in a cylinder 23 in the head 3. Movement of the piston 22 toward the lower end of the cylinder is effective to shift the rod 20 axially of the tool, the rod operating through the medium of suitable cams to positively expand the tool. Movement of the piston 22 in the opposite direction withdraws the push rod from engagement with the rod 20 and permits contraction of the tool by the usual spring-contracting mechanism.

Hydraulic circuits and apparatus

The hydraulic system of the machine illustrated may be considered as comprising three separate but intimately related hydraulic circuit organizations. One circuit is concerned with the reciprocation of the tool, the second with the rotation of the tool and the third with the actuation, that is, the expansion and contraction of the tool. Pressure fluid is supplied to the circuits by the high pressure pump 9 and the low pressure pump 19, both pumps drawing fluid from a common reservoir or sump 26 to which it is returned after use. Each circuit includes suitable valves which may be of the usual and well known construction for controlling the supply of pressure fluid to the cylinder 8, the hydraulic motor 13 and the cylinder 23, respectively.

The hydraulic circuit for reciprocating the tool includes a reversing valve 27 operated under control of a pilot valve 28 to direct pressure fluid into opposite ends of the cylinder 8 alternately. Pressure fluid is supplied to the reversing valve by the pump 9 through pressure ducts 29 and 30 and an "on-and-off" valve 31 when the latter valve is in its "on" position. The valve 31 is interposed between the pressure ducts 29 and 30 and effective in its "off" position to shut off the latter duct and connect the pressure duct 29 with a drain duct 32 which returns the pressure fluid to the sump 26. As herein shown, the valve 31 is biased to the "off" position and a solenoid VS1 is provided for operating it to the "on" position.

The reversing valve 27 has a valve plunger 34 shiftable between two positions in well known manner under control of the pilot valve 28.

When the valve plunger is moved to the left, the upper end of the pressure duct 30 is closed and pressure fluid is directed through a duct 35 to the lower end of the cylinder 8. The piston 6 is accordingly moved toward the upper end of the cylinder and spent pressure fluid is exhausted therefrom through a duct 36, valve 27 and the drain duct 32.

When the valve plunger 34 is shifted to its alternate position, as shown in the drawings, the pressure duct 30 is connected with the duct 36 leading to the upper end of the cylinder 8. The lower end of the cylinder remains connected to the pressure fluid source but due to the greater effective area presented by the upper end of the piston 6, the force exerted on the upper end exceeds that on the lower end and the piston is accordingly moved downwardly. Pressure fluid exhausted from the lower end of the cylinder is returned to the pressure system, thereby reducing the volume required to be delivered by the pump 9. A check valve 37 interposed in the duct 35 serves to equalize the weight of the reciprocating parts.

The pilot valve 28 is actuated at each end of the tool stroke by suitable mechanical control means to be described hereinafter. The arrangement is such that once the machine is started reciprocation of the tool proceeds as long as the valve 31 is held in "on" position by its operating solenoid VS1.

It has been found that a periodic reversal of the direction of rotation of the tool tends to prevent the abrasive elements from "loading" and equalizes wear on the active surface of the elements. This materially improves the cutting efficiency of the abrasive elements and also increases their useful life. Accordingly, the hydraulic circuit for the spindle driving motor 13 includes a reversing valve 38 for controlling the direction of rotation of the motor drive shaft in addition to an "on-and-off" valve 39 for starting and stopping the motor. Pressure is supplied to this circuit by the low pressure pump 19 through a pressure duct 40. The valve 39 which is connected in this duct between the pump and the reversing valve is biased to the "off" position in which it shuts off the supply of pressure fluid from the motor 13 and returns the fluid to the sump by way of the drain duct 32. A solenoid VS2 operatively associated with the valve 39 is effective when energized to operate the valve to the "on" position and thus initiate operation of the motor 13.

The direction in which the motor 13 turns and consequently the direction of rotation of the tool 12, is dependent upon the position of the reversing valve 38. The valve has a plunger 42 actuated by solenoids VS3 and VS4. Solenoid VS3 when energized shifts the valve plunger to one end of the valve casing, thereby connecting the pressure duct 40 with a duct 45 which delivers the fluid to the motor in a manner such that the tool 12 is rotated in a clockwise direction. Spent pressure fluid from the motor is returned to the sump through a duct 46, valve 38 and the drain duct 32.

Solenoid VS4 when energized shifts the valve plunger 42 to the opposite end of the valve casing, thereby connecting the pressure duct 40 with duct 46 to reverse the flow of pressure fluid through the motor 13. The direction of rotation of the motor is accordingly reversed and the tool 12 is rotated in a counterclockwise direction. Spent fluid pressure from the motor is returned to the sump by way of the duct 45, valve 38 and the drain duct 32.

For the reasons pointed out above, it is desirable to carry out the honing operation in different steps or stages such as rough honing and finish honing, in which tool pressure is adjusted to provide maximum cutting action without danger of injury to the tool or work. The hydraulic circuit for expanding and contracting the tool 12 is therefore arranged with a particular view of providing an effective control of the pressure exerted by the tool on the work piece in the different stages of the operation. In the particular embodiment of the invention herein disclosed, a relatively light tool pressure is applied at the beginning of the honing operation and continued until the major irregularities of the surface have been removed. The tool pressure is then increased substantially to enable the tool to operate with maximum efficiency.

The improved method increases the operating efficiency of the machine since it permits the rough work to be honed in a single operation. It is also advantageous in that it reduces to a minimum the strains imposed on the tool and work and materially increases the useful life of the tool.

In the illustrative embodiment of the machine, the means for controlling the pressure exerted by the tool on the work is in the form of a valve 47 which, as herein shown, is arranged for operation by a solenoid VS5. When separate sources of pressure fluid are available, the valve 47 may be utilized to connect either source to the hydraulic circuit of the tool-actuating means selectively. In case only one source of pressure fluid is available, the valve 47 may take the form of a pressure reducing or by-pass valve of any suitable construction. Moreover, the valve 47 may be constructed for operation with more than two sources of pressure fluid or a plurality of such valves may be used to provide for actuating the tool in a greater number of steps if desired.

Referring to the drawings the valve 47 as herein shown is a two-position valve spring biased to a position effective to connect a duct 50 leading from the low pressure pump 19 with a duct 51 extending to a reversing valve 52. The valve 47 when operated to its alternate position by the energization of the solenoid VS5 connects the duct 51 with a duct 53 leading from the high pressure pump 9.

The reversing valve 52, which may be a four-way valve of any suitable and well known construction, is arranged for operation by a solenoid VS6 and is adapted to control the supply of pressure fluid to the cylinder 23 for expanding and contracting the honing tool 12. The valve is spring biased to a position in which it is effective to direct the pressure fluid received via the duct 51 through a duct 54 and a telescoping extensible connection 56 to the lower end of the cylinder 23, thus moving the piston 22 toward the upper end of the cylinder to contract the honing tool. Spent pressure fluid is exhausted from the upper end of the cylinder through a telescoping extensible connection 56, a duct 57, valve 52 and a branch 58 of the drain duct 32.

Energization of the solenoid VS5 reverses the hydraulic circuit connections to the cylinder 23 thereby introducing pressure fluid into the upper end of the cylinder and exhausting the pressure fluid from the lower end of the cylinder. The

piston 22 is thereby moved toward the lower end of the cylinder to expand the honing tool 12.

It will be apparent from the foregoing that by appropriate manipulation of the valves 47 and 52 the tool 12 may be expanded in steps in each of which a different degree of pressure is exerted on the work piece. Likewise, the tool may be contracted when required. Thus, when the valve 47 in its normal unoperated position and solenoid VS6 is energized, pressure fluid from the low pressure pump 19 will be supplied to the cylinder 23 to expand the tool with relatively light pressure. When the valve 47 is operated by the energization of the solenoid VS5, pressure fluid from ths high pressure pump 9 is supplied to the cylinder 23 and the pressure exerted on the work piece by the tool is correspondingly increased. Upon deenergization of the solenoid VS6, pressure fluid is introduced into the lower end of the cylinder 23 thereby contracting the tool, the speed of operation depending upon the position of the valve 47.

Mechanical controls

The mechanical controls for governing the operating cycle of the machine may be generally similar to those disclosed in the application of A. M. Johnson above referred to. They include generally a control rod 61 supported on the frame of the machine for limited rotational and endwise movements. The latter movements of the control rod are utilized to operate the pilot valve 28 through the medium of an arm 62 fast on the rod which cooperates with an operating member 63 forming a part of the valve. These endwise movements are imparted to the control rod by a stop-engaging arm 64 carried on and reciprocable with the head 3. The arm 64 is positioned to engage adjustable stops carried by the control rod incident to the reciprocation of the head. Ordinarily, three stops are provided, namely, an upper limit stop 65, a lower limit stop 66 and an intermediate stop 67. Stops 66 and 67 define the limits of the working stroke of the tool and are accordingly set for engagement by the arm 64 as the tool approaches the ends of the work piece. Stop 65 defines the extreme limit or end of the pull-out stroke in which the tool is withdrawn from the work.

The intermediate stop 67 is so constructed that the arm 64 passes by without shifting the control rod when the head is initially advanced from the withdrawn position to insert the tool into the work. The advance of the head thus continues until the arm 64 engages the stop 66 thereby shifting the control rod and reversing the direction of movement of the head. Upon the return movement the arm 64 engages the intermediate stop 67 and in this case is effective to shift the control rod and again operate the pilot valve to reverse the direction of movement of the tool. Thus, after the tool is inserted in the work, reciprocation through the working stroke is controlled automatically by the pilot valve and associated control mechanism.

To effect withdrawal of the tool from the work, the control rod 61 is rotated sufficiently to move the intermediate stop 67 out of the path of the arm 64. Rotation of the rod may be effected either manually by means of a handle 68 or automatically by a pull-out solenoid PS1. The solenoid PS1 has an armature 69 operatively connected with a lever 70 having a slidable, nonrotatable connection with the control rod. Thus, when the solenoid is energized, the rod is rotated sufficiently to move the intermediate stop 67 out of the path of the arm 64. The movement of the head therefore continues until the arm 64 engages the limit stop 65 and shifts the control rod to operate the pilot valve 28.

Means is provided for interrupting the operation of the machine automatically as an incident to the withdrawal of the tool from the work. As herein shown, this means comprises a limit switch LS1 adapted to be opened by an operating member 71 carried by the head 3. The parts are so positioned that the member engages the switch to open the same immediately following the operation of the pilot valve and before the return movement of the head is started. Thus, the pilot valve is set so that the next operating cycle will begin with an advancing movement of the head. The opening of the switch LS1 interrupts certain of the control circuits to be described in more detail hereinafter.

Automatic means is also provided for initiating operation of the tool-actuating means to expand and contract the tool in proper timed relation to its insertion in or withdrawal from the work. This control is effected through the medium of a control switch CS1 incorporated in the electrical system of the machine so as to control the energization of the reversing valve solenoid VS6 as will be described presently. Opening and closing of the switch CS1 is effected by a switch-actuating member 72 fast on a vertical rock shaft 73 journaled on the frame of the machine. The shaft 73 carries two oppositely facing cam members 74 and 75 engageable by the operating member 71 on the head. The cams are so positioned that when the tool has been advanced substantially entirely into the work, the member 71 engages cam 74 to rock the shaft in a direction effective to close the switch CS1. With the shaft in this position, the cam 75 is moved into the path of the member 71. However, this cam is positioned slightly above the uppermost point reached by the member 71 in the working stroke of the tool so that the cam is engaged only when the tool is being withdrawn from the work. Upon such engagement, switch CS1 is opened and the tool is contracted, thus avoiding any possibility of injuring the tool or work piece by attempting to withdraw the tool while in expanded condition.

Electrical controls

The electrical control system comprises a series of electrically related circuits including relays, automatic control devices and manually operable switches for controlling the various functions of the machine. The control is effected through the medium of valve operating solenoids VS1—VS6 and the control rod operating solenoid PS1 hereinbefore described.

Current for operating the relays and solenoids may be supplied from any suitable source. In the preferred embodiment disclosed, the current for this purpose is obtained from a three-wire power line comprising line conductors L1, L2 and L3. It is preferred to operate the relays at relatively low voltage, and with this in view the circuits are arranged for connecting the relays across the line conductors L1 and L2. Considerable power is required for operating the valves and the control rod with the speed required for proper operation of the machine. Hence the valve operating solenoids are preferably of the high voltage type and the circuits are arranged

to connect them across the outside line conductors L1 and L3.

The operation of the improved control system will be most readily understood when considered in connection with the operation of the machine. Assuming that the machine is in its normal idle condition, as shown in Fig. 1, and that the pump motor 10 is running, an operating cycle may be initiated by a momentry actuation of a normally open manualy operable "start" switch S1 (Fig. 2). This switch closes a circuit for a relay R1. The relay upon energizing closes switches R11, R12 and R13, the second mentioned switch completing a circuit for the solenoid VS1 which accordingly operates the valve 31 to "on" position. Pressure fluid is thus supplied to the upper end of the cylinder 8 to move the tool toward the work. As an incident to such movement, the limit switch LS1 is closed, thereby completing a sealing circuit for the relay R1 by way of the relay switch R11, a normally closed "jog" switch S2 and a normally closed "stop" switch S3. The solenoid circuit is therefore maintained closed and valve 31 is held in the "on" position until the relay is deenergized by opening the switch S3 or the limit switch LS1. Accordingly, the tool is reciprocated through the working stroke under control of the pilot valve 28 in the manner hereinbefore described.

When it is necessary to reciprocate the tool or to advance it toward the work without initiating an operating cycle as, for example, when the machine is being set to operate on a new work piece, the "jog" switch S2 is actuated instead of the switch S1. The switch S2 completes an energizing circuit for the relay R1 but at the same time it opens the sealing circuit for the relay. Thus the valve 31 will be operated to "on" position only as long as the switch S2 is held closed and upon release of the switch the valve will return to "off" position to stop the machine.

Rotation of the tool is initiated by the momentary actuation of a normally open "start" switch S4 which completes a circuit for a relay R2 having normally open switches R21 and R22. The relay closes a sealing circuit for itself by way of the switch R21 and a normally closed "stop" switch S5. Switch R22 completes a circuit for the valve operating solenoid VS2 which operates the valve 39 to "on" position to supply pressure fluid to the spindle motor 13, as previously explained. It will be observed that the initial energizing circuit as well as the sealing circuit for the relay R2 includes the switch R13 of the relay R1. Thus the relay R2 can be energized only when the relay R1 is likewise energized. In other words, rotation of the tool can be initiated only when it is reciprocated. The interlock thus provided between the spindle reciprocating mechanism and the spindle driving motor prevents injury to the tool or work piece by accidental rotation of the tool when the spindle is stationary.

After initiation of an operating cycle in the above manner, expansion of the tool 12 is effected automatically as an incident to its being fully inserted into the work. The initial expansion at low pressure is brought about by the closure of the control switch CS1 which completes a circuit for a relay R3. The relay closes its switch R31 to energize the solenoid VS6 and thereby operate the valve 52 to direct pressure fluid into the upper end of the tool-expanding cylinder 23. Since valve 47 is unoperated at this time, pressure fluid will be supplied to the cylinder from the low pressure pump 19.

Control switch CS1, in addition to closing the circuit for the relay R3, also completes a circuit for initiating the operation of a timing device or timer TM1. The timer may be of any suitable type and as herein shown comprises a suitable motor operated by the current supplied over the circuit closed by switch CS1. Switch-actuating mechanism of well known construction driven by the motor is arranged to close a normally open switch TM12 after the lapse of a predetermined time interval. The timer is preferably adjustable so that the interval required to close the switch may be varied as required.

Closure of the switch TM12 completes a circuit for energizing the solenoid VS5 which operates the valve 47 to cut off the supply of pressure fluid from the low pressure pump 19 and to connect the high pressure pump 9 to the tool-expanding cylinder. Thus the pressure exerted by the tool is increased to enable the tool to operate with maximum efficiency throughout the remainder of the operating cycle. The expansion of the tool in the manner above described has been found to be particularly advantageous in honing work pieces having a relatively rough surface such as that left after a boring operation. The length of the light honing operation may be adjusted so that the major surface irregularities are removed before high pressure is applied to the work by the tool. Thus, the machine is enabled to carry out the improved honing method with a minimum of supervision or attention from the attendant.

The timer switch TM12 may also be utilized to initiate the operation of a control device such as a stroke counter or timer for terminating the operating cycle of the machine at the proper time. In the particular embodiment illustrated, the control device comprises a timer TM2 which may be similar to the timer TM1 above described. The timer has a normally open switch TM21 adapted to be preset manually in well known manner, to close a predetermined time after the timer motor is started. Closure of the switch TM21 completes a circuit for a relay R4 having a normally open switch R41 and a normally closed switch R42. The switch R41 when closed completes a circuit for the pull-out solenoid PS1 which, as previously explained, operates the control rod 61 to move the intermediate stop 67 out of the path of the stop-engaging arm of the head. The head is accordingly moved to its extreme limit position thereby withdrawing the tool from the work and eventually stopping the machine by opening the limit switch LS1.

The switch R42 of the relay R4 is included in the circuit for energizing the tool-expanding relay R3. Accordingly, the opening of this switch is effective to deenergize the relay R3 and thereby interrupt the circuit of the valve solenoid VS6. The valve solenoid immediately releases the valve 52 for retufn to normal position whereby pressure fluid is directed into the lower end of the cylinder 23 to contract the tool. Since release of the valve takes place during a working stroke of the tool, the valve control switch CS1 will be in closed position and the valve solenoid VS5 will be energized so that pressure fluid from the high pressure pump 9 will be supplied to the cylinder 23. The tool will therefore be contracted very quickly, thereby insuring its collapse before it is withdrawn from the work. Thus, any possibility of injury to the tool or work by attempted withdrawal while the tool is expanded is effectually avoided.

Upon withdrawal of the tool, the switch CS1 is opened incident to the engagement of the operat-

ing member 71 with the cam 75 of the switch operating mechanism, thereby opening the circuit of the valve solenoid VS5 to restore the valve 47 to normal position.

Means is provided by which the working stroke portion of the operating cycle may be increased or decreased, as desired, independently of the timer TM2. As herein shown, this means comprises an "increase" switch of the normally closed manually operable type interposed in the circuit of the relay R4 in series with the timer switch TM21 and a normally open "decrease" switch S7 arranged to close the circuit of the relay R4 independently of the timer switch TM21. Thus, when the switch S6 is actuated, closure of the timer switch is ineffective to energize the relay R4, and accordingly reciprocation of the tool through its working stroke continues as long as the switch is held in open position. Upon release of the switch, a circuit for the relay is completed through the timer switch and the operation of the machine is interrupted in the usual manner. Operation of the switch S7 at any time is effective to energize the relay R4 and immediately stop the machine.

A relay R5 is provided for closing the circuits of the valve operating solenoids VS3 and VS4 selectively. As explained hereinbefore, these solenoids when energized operate the reversing valve 38 to control the direction of rotation of the honing tool 12. As herein shown, the relay R5 is provided with two normally open switches R51 and R52 and a normally closed switch R53. The latter switch is connected in the circuit of the valve solenoid VS 4 so that when the relay R5 is in its normal deenergized condition solenoid VS4 is energized and the valve 38 is set to effect rotation of the tool in one direction. The switch R53 is connected in the circuit of the solenoid VS4. Upon energization of the relay R5, solenoid VS3 is energized and solenoid VS4 is deenergized, the valve 38 being operated to the reverse position to effect rotation of the tool in the opposite direction.

Energization of the relay R5 may be controlled either manually or automatically. To this end, two separate circuits are provided for the relay. These circuits are arranged to be connected up selectively by a manually operable switch S8. With the switch S8 operated to the position shown in the drawings the relay is energized upon actuation of a normally open switch S9 and is maintained energized over a sealing circuit including the relay switch R51 and manually operable normally closed "stop" switch S10. Operation of the latter switch is effective to interrupt the circuit of the relay and thus bring about a reversal in the direction of rotation of the tool.

The switch S8 when operated to its alternate position connects up the second circuit for the relay R5 which circuit is arranged to be closed and opened periodically by a motor-operated timer TM3 through the medium of a switch TM31. The timer may be of any suitable construction and as herein shown is equipped with a suitable cam 76 which alternately closes and opens the switch TM31 to energize and deenergize the relay R5. The switch S11, closed simultaneously with the operation of the switch S8 to its alternate position, completes the operating circuit for the timer.

During the honing operation, coolant is supplied to the tool by a suitable pump driven by an electric motor 77. The motor is started by momentary actuation of a normally open switch S12 which completes a circuit for a relay R6. Relay R6 closes switches R61 and R62 thereby completing a sealing circuit for itself and a circuit for a motor switch solenoid MS1. The sealing circuit for the relay includes a normally closed "stop" switch S13 effective when actuated to open the circuit of the relay and thus stop the pump motor. Solenoid MS1 when energized closes a switch MS12 to connect the motor 77 across the power line.

Brief résumé of operation

When initially setting up the machine for operating on a new work piece, the tool may be moved into or out of the work by operation of the "jog" switch S2. Tool movement is under constant control of the attendant and can be interrupted instantly by merely reversing the switch. This materially facilitates the setting up process and effectually eliminates danger of damaging the tool or work by accidental initiation of a reciprocating cycle before the work is properly positioned for operation.

After the work is set up, the timers TM1 and TM2 are adjusted or set to provide the desired operating intervals for low and high pressure operation. The switch S8 is also operated to connect up either the manual or automatic control devices for controlling a direction of rotation of the tool. The coolant pump motor 77 is started by momentary closure of the "start" switch S12.

The operating cycle of the machine is now initiated by momentary closure of the "start" switches S1 and S4, energizing the relays R1 and R2, respectively, to start reciprocation and rotation of the tool. Switch S1 is held closed until the tool head moves away from its limit position sufficiently to close the limit switch LS1. The operation of the machine is then continued independently of the starting switch due to the relays R1 and R2 being maintained in energized condition over self-closed sealing circuits.

The tool is advanced into the work in a collapsed condition, and when fully inserted in the work is expanded incident to the closure of the control switch CS1 which completes a circuit for the relay R3 and the timer TM1. Relay R3 completes a circuit for the valve solenoid VS6 and the solenoid operates the valve 52 to tool-expanding position. Pressure fluid from the low pressure pump 19 is accordingly supplied to the upper end of the tool-expanding cylinder 23 and the tool is expanded with relatively light pressure. Reciprocation of the tool through the working stroke continues with the tool thus expanded until the timer TM1 closes the switch TM12. Closure of the latter switch completes a circuit for the solenoid VS5 and a circuit for the timer TM2. Solenoid VS5 shifts the valve 47 to direct pressure fluid from the high pressure pump into the tool-expanding cylinder, thus materially increasing the pressure exerted by the tool on the work.

Reciprocation of the tool through the working stroke continues until the timer TM2 closes the switch TM21 to energize the relay R4. Energization of this relay brings about the energization of the pull-out solenoid PS1 and the deenergization of the relay R3. Solenoid PS1 rocks the control rod 61 to move the intermediate stop 67 out of the path of the arm 64 so that in the next return stroke the tool head will move to its extreme limit position and open

the limit switch LS1. Deenergization of relay R3 interrupts the circuit of the solenoid VS6 which releases the valve 52, thereby directing the pressure fluid into the lower end of the cylinder 23 to contract the tool.

During the honing operation, the direction of rotation of the tool is automatically reversed under control of the timer TM3. The timer closes and opens its switch TM31 periodically to energize and deenergize relay R5. Relay R5 closes circuits alternately for the valve solenoids VS3 and VS4 which accordingly operate the valve 38 to cause the motor 13 to rotate first in one direction and then in the opposite direction. This reversal may be effected manually instead of automatically, if desired, by operation of the switches S8, S9 and S10.

The movement of the head to its limit position withdraws the tool from the work, operates the pilot valve to its alternate position and opens the control switch CS1. Opening of the limit switch LS1 stops the machine by opening the circuit of the relay R1, which relay in turn opens the circuit of the relay R2. These relays, as above explained, control reciprocation and rotation of the tool respectively. With the switch CS1 open, solenoid VS5 is deenergized and valve 47 is returned to normal position. Likewise, with the pilot valve 28 operated to its alternate position, reversing valve 27 is set to direct pressure fluid into the upper end of the cylinder 8. Thus the machine is conditioned for the next operating cycle.

It will be apparent from the foregoing that the invention provides a new and improved method of honing cylindrical surfaces together with a honing machine of novel and advantageous construction particularly adapted to carry out the improved method. The machine embodies suitable means by which the direction of rotation of the tool may be reversed either manually or automatically at predetermined intervals, to enable the tool to operate with maximum efficiency. The machine likewise embodies novel means by which the tool may be actuated in steps to exert different degrees of pressure upon the work piece in different stages of the honing operation.

The invention also provides a control system of novel character which materially simplifies the work of the attendant in controlling the operation of the machine. The various machine elements are under complete control of the operator at all times and capable of being started and stopped by simple actuation of push button control switches. The control system includes automatic devices by which the different stages of the working stroke cycle may be controlled without the intervention of the attendant. It likewise includes novel means for terminating the operating cycle of the machine subject to instant change by the attendant whenever necessary.

We claim as our invention:

1. In a machine for honing cylindrical surfaces, in combination, a honing tool having a plurality of abrasive elements arranged in a circular series, tool-actuating means operative to shift said elements radially to force the elements into engagement with the surface of a cylindrical work piece, a support for said tool, a support for the work piece, means for reciprocating one of said supports relative to the other support to cause the tool to operate on the surface of the work piece, means for rotating one of said supports during said reciprocation to effect relative rotation of the tool and work, hydraulically-operated means for operating said tool-actuating means to force the abrasive elements of the tool against the work piece, a first and a second source of pressure fluid, the fluid supplied from said second source being at a higher pressure than the fluid supplied from said first source, a valve operable to connect either of said sources to said hydraulically-operated means selectively, and a timing device for operating said valve.

2. In a machine for honing cylindrical surfaces, in combination, a honing tool having a plurality of abrasive elements arranged in a circular series, tool-actuating means operative to shift said elements radially to force the elements into engagement with the surface of a cylindrical work piece, a support for said tool, a support for the work piece, means for reciprocating one of said supports relative to the other support to cause the tool to operate on the surface of the work piece, means for rotating one of said supports during said reciprocation to effect relative rotation of the tool and work, hydraulically-operated means for operating said tool-actuating means to force the abrasive elements of the tool against the work piece, a first and a second source of pressure fluid, the fluid supplied from said second source being at a higher pressure than the fluid supplied from said first source, and means for connecting either of said sources to said hydraulically-operated means selectively.

3. In a honing machine, in combination, an expansible and contractible honing tool, means for supporting work to be operated on by the tool, means for effecting relative rotation and reciprocation of the tool and work, hydraulically-actuated means including a cylinder and piston mechanism for expanding and contracting the tool, a low pressure fluid source and a high pressure fluid source, a valve normally effective to supply pressure fluid from said low pressure source to said hydraulically-actuated means, means for operating said valve to supply pressure fluid from said high pressure source to said hydraulically-actuated means, a second valve operable to direct pressure fluid into opposite ends of said cylinder alternately to expand and contract the tool, and means for operating said valves.

4. In a honing machine, in combination, an expansible and contractible honing tool, hydraulically-actuated means for expanding and contracting the tool to engage and disengage the surface of the work being operated on, means for effecting relative rotation and reciprocation of the tool and work, a source of high pressure fluid, a source of low pressure fluid, a valve normally effective to connect said low pressure source to said hydraulically-actuated means to expand the tool, and means for operating said valve to connect said high pressure source to said hydraulically-actuated means whereby to increase the pressure exerted by the tool on the work.

5. In a machine for dressing cylindrical surfaces by rough and finish honing operations, means for rubbing a plurality of abrasive elements over the surface with a combined rotary and reciprocatory motion, means for forcing the elements against the surface with a different pressure in each of said operations, and a separate timing device for terminating each operation.

6. In a machine for honing cylindrical surfaces, in combination, a cylindrical expansible and contractible tool, hydraulically-actuated

means for expanding and contracting the tool, power-driven means for effecting relative rotation and reciprocation of the tool and the surface being operated on, a first timing device operative to control said hydraulically-actuated means, and a second timing device operative to control said power-driven means.

7. In a honing machine, in combination, an expansible and contractible honing tool, hydraulically-actuated means for expanding and contracting the tool to engage and disengage the surface of the work being operated on, means for effecting relative rotation and reciprocation of the tool and work, a source of high pressure fluid, a source of low pressure fluid, and valve means operable to supply pressure fluid from either source to said hydraulically-actuated means to control the pressure exerted by the tool on the work.

8. In a machine for honing the internal surfaces of cylinders, in combination, an expansible and contractible honing tool, means for supporting a work piece to be operated on by said tool, means for moving the tool into the work piece while the tool is contracted, means for expanding the tool to exert a predetermined pressure upon the work piece, means for rotating and reciprocating the tool in the work piece to dress the surface thereof, a timing device initiated in operation upon the expansion of said tool, and means controlled by said timing device for increasing the pressure exerted by the tool on the work piece.

9. In a machine for honing cylindrical surfaces, in combination, an expansible and contractible honing tool, means for supporting work to be operated on by said tool, means for effecting relative rotation and reciprocation of the tool and work, power-actuated means for expanding the tool into engagement with the surface of the work, means operative to increase the pressure exerted by the tool on the work, a timing device for controlling the operation of said pressure increasing means, a second timing device, and means controlled by said second device for interrupting the relative rotation and reciprocation of the tool and work.

10. In a machine for honing cylindrical surfaces, in combination, an expansible and contractible honing tool, means for supporting a work piece to be operated on by said tool, means for moving the tool into operative relation to the work piece while the tool is contracted, means for expanding the tool to exert a predetermined pressure upon the work piece, means for rotating and reciprocating the tool relative to the work piece to dress the surface thereof, a first timing device and a second timing device, means controlled by said first timing device for increasing the pressure exerted by the tool on the work piece, and means controlled by said second timing device for contracting the tool and for effecting withdrawal of the tool from the work.

11. In a honing machine, in combination, a honing tool, a support for said tool, a support for work to be operated on by said tool, means for reciprocating one of said supports relative to the other support to traverse the tool over the surface of the work, power-actuated means for rotating one of said supports to effect a relative rotation of the tool and work, a timing device, and means controlled by said device for reversing the direction of rotation of said support.

12. In a honing machine, in combination, a support for a honing tool, a support for work to be operated on by said tool, power-actuated means for reciprocating one support relative to the other support, power-actuated means for rotating one of said supports, power-actuated means for expanding and contracting the tool, electrical control means for said power-actuated means, circuits for the electrical control means of said first and second power-actuated means, manually operable switches for opening and closing said circuits to start and stop rotation and reciprocation of said supports, a circuit for the control means of said third power-actuated means, and a switch for opening and closing said last circuit operable by the reciprocating support.

13. In a honing machine, in combination, a honing tool having a plurality of abrasive elements arranged in circular series, tool-actuating mechanism operative to shift the abrasive elements radially to force them into operative engagement with the surface of a cylindrical work piece, a support for the tool, a support for the work piece, means for reciprocating one of said supports relative to the other support to traverse the tool axially of the work piece, means for rotating one of said supports during said reciprocation to effect relative rotation of the tool and work, pressure fluid means for operating said tool-actuating mechanism to force the abrasive elements of the tool against the surface of the work piece, a valve controlling the supply of pressure fluid to said pressure fluid means to vary the pressure exerted by the abrasive elements on the work piece, and means for operating said valve to cause the tool to exert a relatively light pressure in the initial stage of the honing operation and a substantially higher pressure at a succeeding stage of the honing operation.

14. In a honing machine, in combination, a honing tool having a plurality of abrasive elements arranged in circular series, tool-actuating mechanism operative to shift the abrasive elements radially to force them into operative engagement with the surface of a cylindrical work piece, a support for the tool, a support for the work piece, means for reciprocating one of said supports relative to the other support to traverse the tool axially of the work piece, means for rotating one of said supports during said reciprocation to effect relative rotation of the tool and work, pressure fluid means for operating said tool-actuating mechanism to force the abrasive elements of the tool against the surface of the work piece, a valve for controlling the pressure of the fluid supplied to said fluid operated means and operable to vary the pressure exerted by the abrasive elements on the work piece, and means for automatically operating said valve during the honing operation.

15. In a honing machine, in combination, an expansible abrasive tool, means for supporting work to be operated on by said tool, means for effecting relative rotation of the tool and work, means for effecting relative reciprocation of the tool and work through a definite working cycle, power-actuated means for expanding the tool to exert a predetermined pressure on the work upon initiation of said working cycle, and means operable automatically a predetermined time after the initiation of the working cycle for modifying the action of said power-actuated means to change the pressure exerted by the tool on the work.

16. A method of honing cylindrical work to exact dimensions and with a true contour and smooth surface finish which comprises effecting relative rotation and reciprocation of an

expansible abrasive tool and the work for a definite interval, expanding the tool against the surface of the work with a relatively light pressure during an initial portion of said interval sufficient to remove the major surface irregularities from the work, and substantially increasing the pressure of the tool against the work for the remainder of the interval, the increased pressure being such as to enable the tool to finish the work to the desired dimension.

17. In a honing machine, in combination, a honing tool, a support for said tool, a support for work to be operated on by said tool, means for effecting relative reciprocation of said supports to traverse the tool over the surface of the work, power-actuated means for rotating one of said supports to effect a relative rotation of the tool and work, and means automatically operative at predetermined intervals for reversing the direction of rotation of said one support without interrupting the relative reciprocation of the supports.

18. In a honing machine, in combination, a support for a honing tool, a support for work to be operated on by the tool, power-actuated means for initially moving one support relative to the other support to operatively associate the tool and work and for subsequently effecting relative reciprocation of the supports through a working cycle in which the tool is repeatedly traversed over the work, power-actuated means for rotating on of said supports during the working cycle, control mechanism for said power-actuated means including manually operable means effective to initiate the operation of the power-actuated means, means for continuing the operation of said power-actuated means independently of said manually operable means, an electrically driven timing device, means for automatically initating the operation of said device after the tool and work are brought into operative association, and means controlled by said device for stopping said power-actuated means to terminate the working cycle.

ALBERT M. JOHNSON.
WALTER M. FAIRBAIRN.