

April 19, 1938.

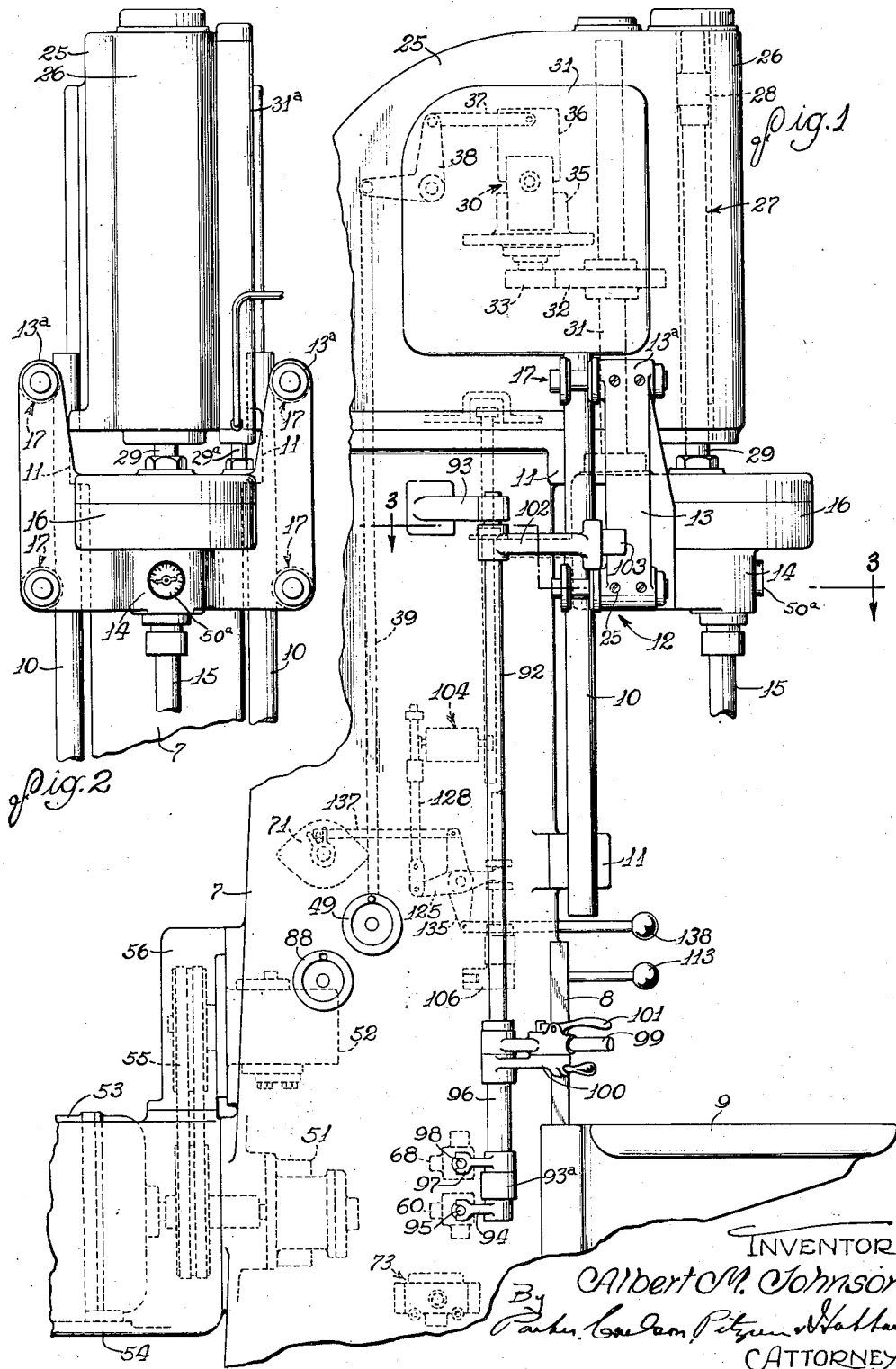
A. M. JOHNSON

2,114,349

HONING MACHINE

Filed June 29, 1936

4 Sheets-Sheet 1



April 19, 1938.

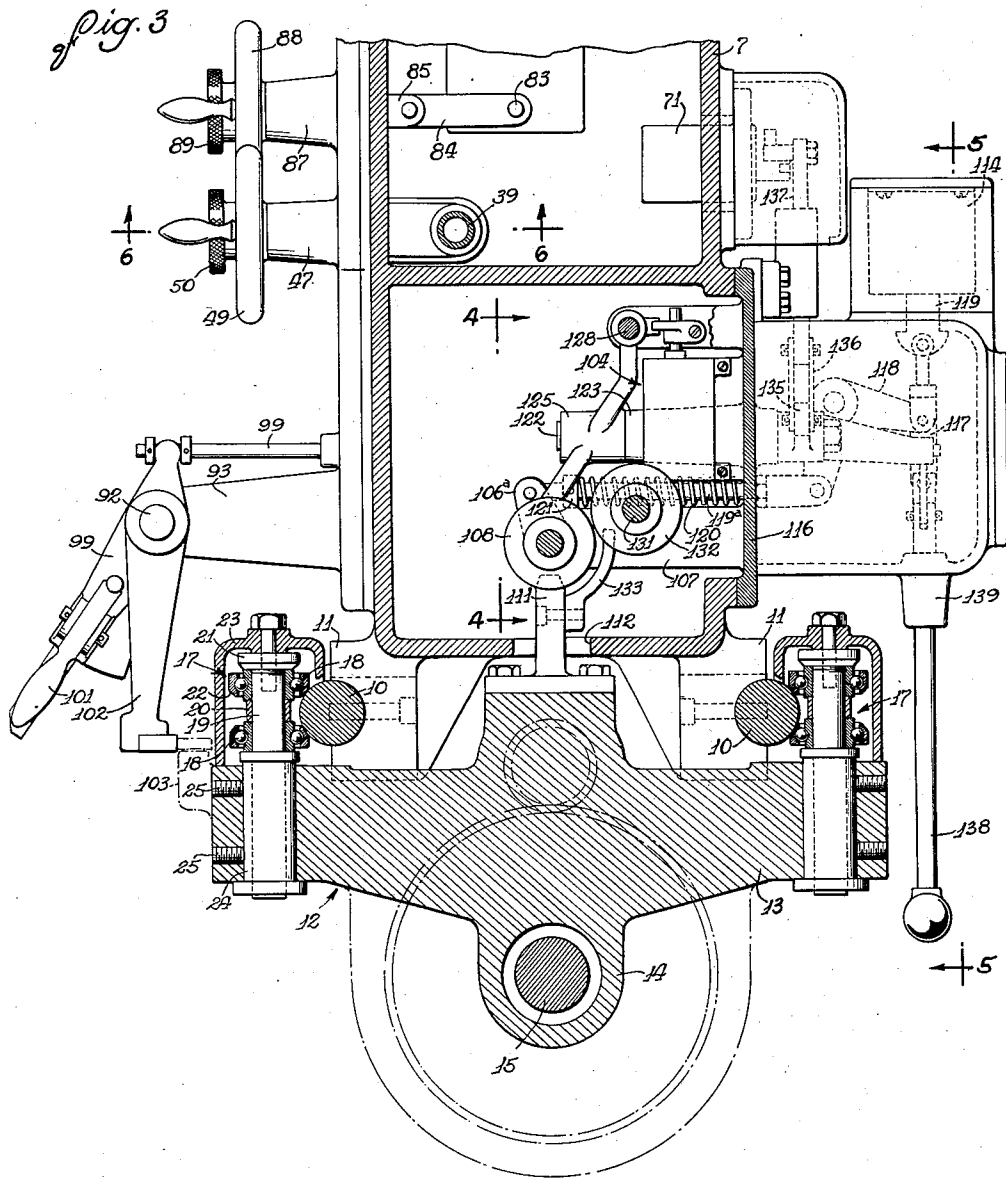
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2,114,349

HONING MACHINE

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4 Sheets-Sheet 2



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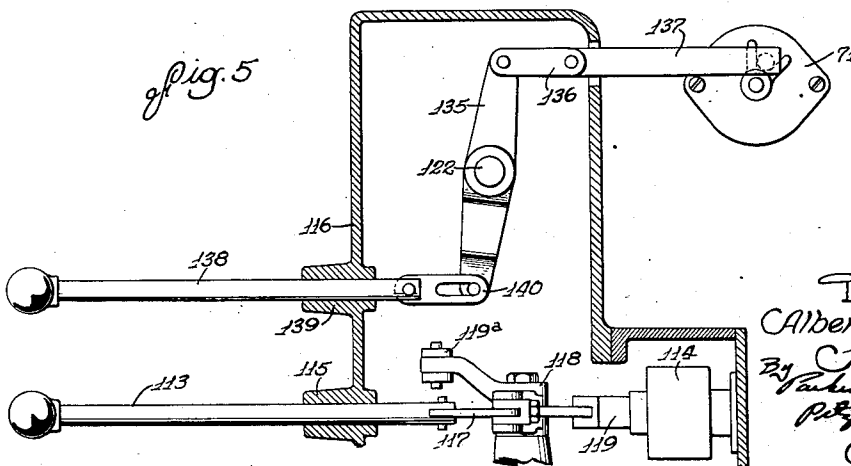
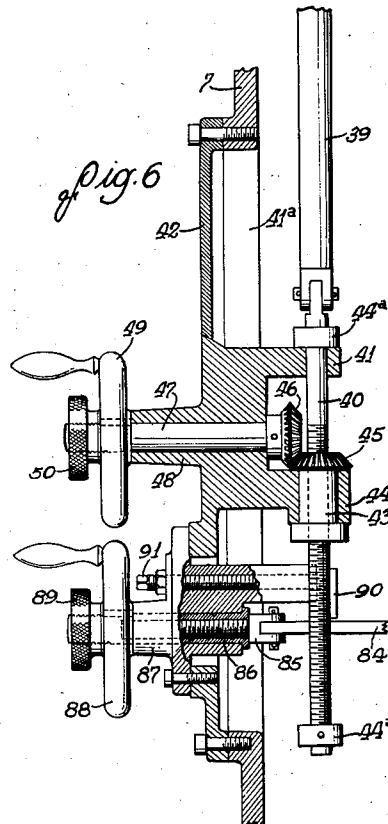
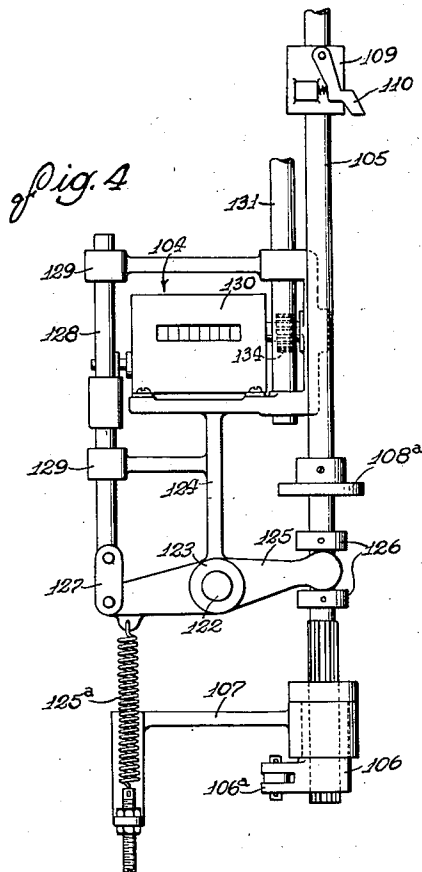
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2,114,349

HONING MACHINE

Filed June 29, 1936

4 Sheets-Sheet 3



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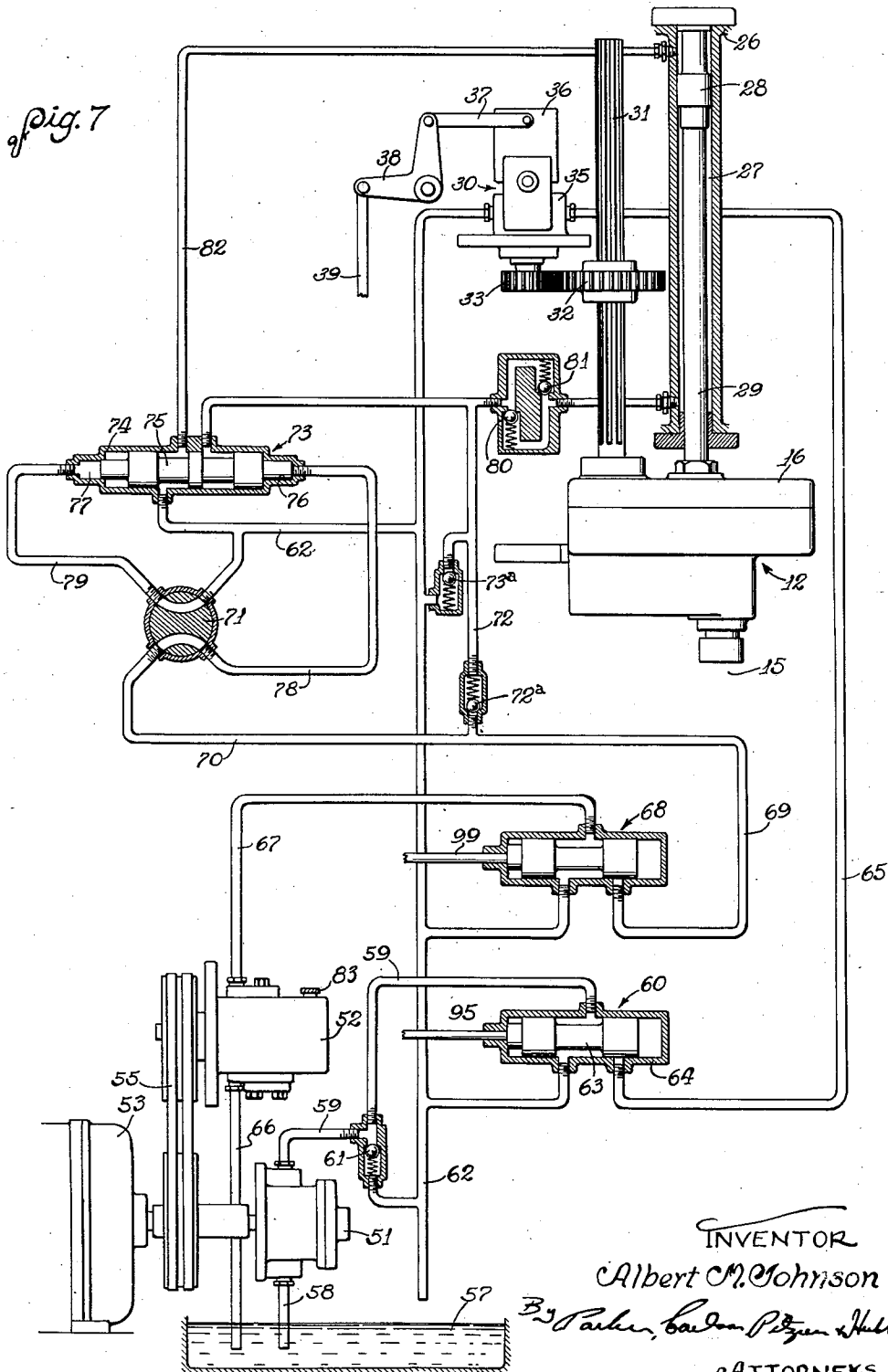
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HONING MACHINE

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4 Sheets-Sheet 4



UNITED STATES PATENT OFFICE

2,114,349

HONING MACHINE

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Application June 29, 1936, Serial No. 87,842

9 Claims. (Cl. 51—34)

The invention relates to honing machines of the type in which a rapidly rotating cylindrical abrasive tool or hone is reciprocated in operative contact with a hollow cylindrical body to dress the surface thereof to a true contour and smooth finish.

The cutting efficiency of the honing tool is dependent largely upon its surface speed relative to the work. Optimum surface speeds vary according to the type of abrasive used and the character of the material constituting the work. For example, a different surface speed is desirable for cast iron than is used for steel or bronze. Likewise, hones designed for producing a mirror finish are preferably operated at different speeds than those used for rougher finishes.

The surface speed of the hone is determined, of course, by its diameter and the rate at which it is rotated and reciprocated. It has been found that, to produce the most satisfactory surface finish, it is essential that the two movements of the hone be properly coordinated; that is, the hone must be reciprocated in definite timed relation to its rotation. Accordingly, accurate adjustment of both rotational and reciprocal speeds is necessary to obtain the proper surface speed of the tool at which it is capable of operating efficiently with different types of honing tools or on cylinders of different materials or of different diameters.

With the foregoing in view, it is the principal object of the invention to provide an improved honing machine adapted to handle a wide variety of work which is capable of operating with maximum efficiency on any class of work within the capacity of the machine. This object is attained through the provision of hydraulic driving mechanism of an advantageous character whereby the rotative speed of the hone as well as its reciprocal speed can be varied infinitely within practical desirable limits.

Another object is to provide an improved hydraulic system for a honing machine by which the hone may be rapidly reciprocated without shock or vibration and by which the stroking may be effected with materially greater uniformity than has heretofore been possible in honing machines employing hydraulic means for reciprocating the hone.

Still another object is to provide an improved reciprocatory tool spindle carriage and support therefor together with improved means for driving the spindle.

Further objects of the invention reside in the improved construction and arrangement of the

control mechanism and the frame work of the machine to provide for the complete enclosure of the mechanism.

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

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

Fig. 2 is a front elevational view of the upper part of the machine.

Fig. 3 is a sectional view through the machine taken along the line 3—3 of Fig. 1.

Fig. 4 is a detail view taken along the line 4—4 of Fig. 3 showing a part of the control mechanism.

Fig. 5 is a view, partly in section, taken along the line 5—5 of Fig. 3 showing another part of the control mechanism.

Fig. 6 is a view, partly in section, taken along the line 6—6 of Fig. 3, showing the adjusting instrumentalities for the hydraulic drive mechanism.

Fig. 7 is a diagrammatic view of the hydraulic circuits and drive mechanism of the machine.

For purposes of disclosure, a preferred form of the invention is illustrated in the drawings and will hereinafter be described in detail as applied to a vertical type honing machine, but it is to be understood that various changes and modifications in form, construction and arrangement may be made by those skilled in the art without departing from the spirit and scope of the invention as defined by the appended claims.

The machine selected to illustrate the invention comprises a hollow upright frame member or column 7 (Figs. 1, 2 and 3) of generally rectangular cross-section carrying on its front face a pair of vertical slideways 8 adjustably supporting a work table 9. A pair of vertically disposed cylindrical guide bars 10 carried on suitable brackets 11 projecting forwardly from the column are arranged above the slideways and constitute a track or guideway supporting a reciprocatory spindle carriage 12 for movement toward and from the work table.

The spindle carriage 12, as shown in Figs. 1, 2 and 3, includes a suitable base 13 having at its lower end a generally cylindrical casing 14 in which a tool spindle 15 is journaled. The spindle carries a conventional abrasive tool or hone (not shown) for operating on work supported on the table 9. A gear box 16 formed integrally with the base and casing or suitably secured thereto

encloses a train of gears for rotating the spindle 15.

For supporting the spindle carriage on the guide bars 10, the base 13 carries a set of generally spool-shaped rollers 17, two of the rollers being located at each side of the base and spaced substantially apart longitudinally of the base. Adequate spacing of the rollers is obtained without necessitating undue lengthening of the column of the machine by the particular construction of the base 13 wherein the side portions thereof are in the form of upwardly extending legs 13^a. The rollers 17 are engageable with the respective guide bars as shown in Figs. 1, 2 and 3, and, by reason of their spacing, serve to hold the carriage in exact alinement regardless of lateral strains imposed by the driving or counterbalancing mechanism.

As herein shown, the rollers 17 each consist of a pair of conventional roller bearing units 18 mounted on a stud 19 projecting rearwardly of the base. The bearing units are spaced apart by means of a sleeve 20 interposed between their inner race rings and are held in place by a collar 21 bolted to the end of the stud. To provide a substantial contact surface for engagement with the guide bar, the adjacent edges of the outer race rings of the units are chamfered as at 22. A generally cylindrical guard 23 having an opening on the side adjacent the guide bar is also secured to the stud 19 to protect the bearings from dirt or grit.

To provide for the adjustment of the rollers 17 relative to the guide bars to take up any play due, for example, to wear of the parts, the supporting stud 19 is mounted in an aperture formed eccentrically in a sleeve 24. The sleeve is rotatably supported in a suitable aperture in the base 13 and is normally held immovable by a pair of locking screws 25. Thus, by simply loosening the screws 25 and rotating the sleeve, the rollers can be moved into tight engagement with the guide bars and the rollers are thus enabled to hold the carriage rigidly against lateral movement while offering a minimum of resistance to its reciprocating movement.

Mounted on the upper end of the column 7 is a head 25 having an extension 26 projecting forwardly to overhang the work table 9 and spindle carriage 12. A vertical bore 27 in the extension of the head constitutes an operating cylinder for a piston 28 which is utilized as a reciprocatory hydraulic motor to reciprocate the spindle carriage through the medium of a piston rod 29.

A pneumatic counterbalancing device is provided to relieve the piston 28 of the weight of the spindle carriage and insure uniform smooth stroking of the honing tool. To this end, the carriage is connected by a piston rod 29^a with a piston reciprocable in a pneumatic cylinder 31^a supported at one side of the cylinder extension 26 with its axis parallel to the axis of movement of the carriage. Air under pressure supplied to the lower end of the cylinder 31^a acts on the piston to support the weight of the carriage. By mounting the cylinder at one side of the carriage reciprocating cylinder 27, as shown in Fig. 2, rather than in axial alinement therewith, the overall height of the machine is kept at a minimum. This arrangement is made practicable by reason of the roller support provided for the carriage which holds the carriage in proper alinement and effectually prevents it from jamming on the ways due to the off-center mounting of the counterbalancing device.

The head 25 also constitutes a housing for a hydraulic spindle rotating motor 30 and to this end is constructed to provide a chamber in which the motor and associated apparatus are supported. Access to the motor is provided by a suitable opening in the side of the head which may be closed by a removable cover plate 31. Preferably, the head 25, including the cylinder extension 26, is made as a unitary casting thereby providing a strong and extremely rigid construction and reducing the number of separate parts required for the machine with a resultant reduction in the cost of its manufacture.

As will be seen by reference to Fig. 7 of the drawings, the motor 30 is drivably connected with the spindle 15 through the medium of a drive shaft 31 and the gear train enclosed in the gear box 16 of the spindle carriage which may be of any suitable type. The shaft 31 has a splined connection with a spur gear 32 journaled in the lower part of head 25, the spur gear being driven by a pinion 33 fast on the shaft of the motor. Thus, the motor 30 is enabled to rotate the spindle 15 while the carriage is reciprocated by the piston 28 operating in the cylinder 27 to produce the particular movements of the honing tool characteristic of the honing operation. In this connection likewise, the roller mounting of the carriage is advantageous as it effectually counteracts the torque exerted on the carriage incident to the rotation of the tool and thus prevents the carriage from jamming on the ways.

It is preferable that hydraulic motors be utilized for rotating and reciprocating the tool spindle since, with motors of this character, the rotative and reciprocal speeds of the spindle and the hone which it carries are susceptible of infinite variation within predetermined minimum and maximum limits. This arrangement is particularly advantageous in a honing machine as it enables the machine to be quickly and easily adjusted to operate with maximum efficiency on different classes of work and to produce the desirable smooth true surface finish.

As herein shown, the hydraulic motor 30 is of the well-known multi-cylinder, oil operated, rotary type having a drive shaft section 35 and a cylinder block section 36 arranged for angular movement relative to each other to vary the rotative speed of the motor drive shaft. A motor of this type is preferred for rotating the tool spindle since its speed may be varied without restricting the flow of pressure fluid.

When the preferred type of hydraulic motor is employed, the drive shaft section 35 of the motor is stationarily mounted in the head 25 and means is provided for manually adjusting the position of the cylinder block 36 to control the speed of the motor. To this end, the cylinder block is connected by a short link 37 with one arm of a bell crank lever 38 pivotally supported in the head 25 as shown in Figs. 1 and 7. Secured to the other arm of the bell crank lever is a second link 39 which extends downwardly into the column 7 and has a pin connection with an actuating rod 40 (Fig. 6).

Referring more particularly to Fig. 6, the actuating rod 40 is slidably supported for vertical movement by a bracket 41 carried by a plate 42 which is adapted to be bolted to the side of the column 7 adjacent an opening 41^a formed therein. A portion of the rod is threaded for engagement with the internal threads of a sleeve 43 rotatably supported by a bracket 44 also carried by the plate 42. Thus, when the sleeve is ro-

tated, the rod 40 is shifted axially by reason of the threaded connection between the parts, and the movement of the rod is transmitted through the linkage to the cylinder head 36 to adjust the position of the same. Collars 44^a fast on the rod act as stops to prevent it from being moved too far in either direction.

As herein shown, the sleeve 43 carries at its upper end a bevel gear 45 meshing with a pinion 46 fast on a transverse shaft 47 journaled in a bearing 48 forming a part of the plate 42. Rotation of the shaft and gear 46 to rotate the sleeve 43 is effected by means of a hand wheel 49 keyed to the outer end of the shaft. A knurled lock nut 50 threaded on the shaft provides a means for locking it against accidental movement. It will be apparent that, with the arrangement shown, the operating speed of the motor 30 may be quickly and easily regulated by simply turning the hand wheel 49. Accurate adjustment is readily obtained since movement of the hand wheel through a relatively large angle produces only a small axial movement of the actuating rod 40 and connecting linkage with a correspondingly small angular movement of the motor cylinder block 36. A tachometer 50^a may be mounted on the spindle carriage and operatively associated with the tool spindle 15 to give a visual indication of the rotative speed of the spindle and thus facilitate adjustment of the same.

Pressure fluid for operating the motor 30 and for reciprocating the piston 28 in the cylinder 27 is supplied by pumps 51 and 52, respectively, through a system of ducts and control valves all of which are enclosed in the hollow column 7. Referring to Fig. 1, it will be observed that the pump 51 is mounted on the rear wall of the column adjacent the base thereof and is directly coupled with an electric motor 53 supported on a bracket 54 mounted on the outside wall of the column. The pump 52 is mounted on the rear wall of the column immediately above the pump 51 and, in the present instance, is driven by the motor 53 through the medium of a V-belt driving connection 55 enclosed in a suitable housing 56 secured to the column. By thus mounting the motor 53 and the pressure fluid pumps adjacent the base of the column, a well-balanced machine results and vibration is reduced to a minimum.

The pump 51, which supplies pressure fluid to the hydraulic motor 30 may be of any suitable type designed to deliver a constant volume of fluid at the desired pressure. As shown in Fig. 7, the pump is arranged to draw fluid from a storage reservoir or sump 57 through an intake duct 58 and discharge it through a pressure duct 59 leading to a control valve 60. A relief valve 61 interposed in the duct 59 operates in case the pressure in the line becomes excessive to by-pass the pressure fluid to the sump by way of a return duct or drain 62.

The valve 60 which controls the delivery of pressure fluid to the hydraulic motor 30 is of conventional type and includes a valve member 63 in the form of a plunger having a pair of spaced piston enlargements reciprocable in a cylinder 64. Actuation of the valve member to open or close the valve is effected either manually or automatically as will appear presently. With the valve member positioned at the left hand end of the cylinder as shown in the drawings, pressure fluid delivered through the duct 59 is returned to the sump by way of the drain 62. When the valve member is moved to the right, the pressure fluid is directed to a duct 65 leading to the hydraulic

motor 30, thus causing the motor to operate. Spent pressure fluid from the motor is returned to the sump by way of the drain 62. It will be apparent that the motor 30 may be started and stopped by opening or closing the valve 60.

The pump 52, which supplies pressure fluid to the spindle carriage reciprocating cylinder 27 may be of the variable volume type, although a constant volume pump together with suitable throttle valves may be employed if desired. Thus, by adjusting the output of the pump, the reciprocal speed of the spindle carriage may be varied in incremental steps to coordinate this movement with the rotative movement of the tool.

Referring to Fig. 7, the pump 52 is arranged to draw pressure fluid from the sump 57 through an inlet duct 66 and to discharge the fluid under pressure into a pressure duct 67 leading to a control valve 68. The valve 68 is of the same construction as the valve 60, hereinbefore described and is operable both manually and automatically to start and stop reciprocation of the spindle carriage as will be described presently.

The valve 68 has two outlet ports, one port being connected to the drain 62 so that when the valve is in closed position, pressure fluid delivered through the duct 67 is returned to the sump 57. The other outlet duct connects with a pressure duct 69 which divides into two branches, one branch 70 leading to a pilot valve 71 and the other branch 72 leading to a reversing valve 73 and to the lower end of the cylinder 27. A check valve 72^a interposed in the duct 72 operates to maintain suitable pressure in the hydraulic system at all times while a relief valve 73^a connected between the duct 72 and the drain 62 prevents the building up of excessive pressure in the system.

The reversing valve 73 controls the delivery of pressure fluid to the cylinder 27 and, in turn, is controlled by the pilot valve 71. The latter valve is of the well-known rotary type operable when turned through a quarter revolution to connect either of two pairs of ports. The valve 73 comprises a cylindrical casing 74 in which is disposed a plunger 75 constituting the movable valve member. The plunger 75 is provided with three spaced piston enlargements designed to connect an outlet port with either an inlet port or a drain port according to the position of the plunger.

The ends of the plunger 75 constitute pistons adapted to operate in cylinders 76 and 77 formed respectively in opposite ends of the casing into which pressure fluid is introduced alternately by the operation of the pilot valve 71, the pressure fluid acting to shift the plunger to the left or right according to the position of the pilot valve. Thus, with the pilot valve in the position shown in the drawings, pressure fluid from the duct 70 is delivered through a duct 78 into the cylinder 76 and the plunger 75 is shifted to the left. Fluid from the cylinder 77 is simultaneously discharged through a duct 79 and the pilot valve to the drain 62. When the pilot valve is given a quarter turn, the pressure duct 70 is connected to the duct 79 and the duct 78 is connected to the drain 62, thereby causing the plunger to be shifted to the right.

As will be seen by reference to Fig. 7, valve 73 when positioned as shown in the drawings, closes one outlet of the pressure duct 72 so that the full supply of pressure fluid is delivered to the lower end of the cylinder 27. Interposed in series in the pressure line leading to the lower end of the

cylinder 27 are a check valve 80 for permitting the free passage of fluid to the cylinder, and a foot valve 81 through which fluid is exhausted from the lower end of the cylinder. The foot valve 81 may be set to open at a predetermined pressure sufficient to substantially counterbalance the weight of the head and thus assists the pneumatic counterbalancing device in maintaining uniform movement of the head in each stroke of the piston.

During the upward travel of the piston 28 fluid is exhausted from the upper end of the cylinder through a duct 82 and the valve 73 to the drain 62. When the valve 73 is reversed, the pressure duct 72 is connected to the duct 82 so that both ends of the cylinder 27 are open to the pressure fluid. Due to the presence of the piston rod 29 in the lower end of the cylinder, however, the effective area presented by the top of the piston 28 is greater than the effective area of the bottom of the piston. The pressure fluid introduced into the upper end of the cylinder is accordingly effective against this differential area to force the piston downwardly in the cylinder. In this downward movement of the piston, the fluid from the lower end of the cylinder is exhausted through the foot valve 81 into the pressure duct 72 and reinforces the supply of fluid delivered to the upper end of the cylinder. With proper proportioning of the bottom and top areas of the piston 28 and the proper adjustment of the foot valve 81, absolute uniformity of stroking which is essential for extremely accurate work is readily obtained.

As explained heretofore, the pressure fluid supplied by the pump 52 to the spindle carriage reciprocating cylinder 27 is varied to control the reciprocating speed of the tool spindle. In the particular pump herein shown, variation of the pressure fluid supply is effected by varying the output of the pump through the medium of an adjusting member 83 (see Fig. 7) located on the top of the pump. To facilitate such positioning of the member 83, a simple and accurate adjusting mechanism readily accessible for manual actuation by an attendant is provided.

As shown in Figs. 3 and 6, the adjusting mechanism is mounted on the plate 42 at one side of the column 7 and closely adjacent the pump 52. A bar 84 connects the adjusting member 83 of the pump with one end of a rod 85 which is threaded into a sleeve 86 rotatably supported in a bearing 87 bolted or otherwise secured to the plate 42. Rotation of the sleeve 86 is effected by means of a hand-wheel 88 keyed to the outer end of the sleeve. The rotation of the sleeve produces an axial movement of the rod 85 by reason of its threaded connection with the sleeve, and the movement of the rod is transmitted to the pump adjusting member 83 by the bar 84. A knurled lock nut 89 threaded onto the end of the sleeve enables the handwheel to be clamped tightly against the end of the bearing 87 and thus prevents accidental operation of the adjusting mechanism. Inward movement of the rod 85 is limited by a stop 90 supported on an extension of the bearing 87 for engagement with the end of the rod, the position of the stop being adjustable through the medium of an adjusting screw 91 threading into the bearing member.

Suitable control means are provided for controlling the various operations of the machine. In general, the control means may be said to conform closely to those shown in my prior Patent No. 1,945,045, granted January 30, 1934,

with certain modifications in the construction and arrangement of the parts to provide a simple and more compact assembly and to enable the controls to be enclosed within the frame of the machine.

Referring first to Fig. 1, the machine is started and stopped by means of well-known control mechanism operating in conjunction with the control valves 60 and 68 whose function has been discussed hereinbefore. The mechanism includes a vertically disposed shaft 92 rotatably supported by brackets 93 and 93^a at one side of the column 7. The shaft carries a valve operator 94 in the form of a crank arm operatively connected with the plunger of the valve 60 by a rod 95. A sleeve 96 rotatably mounted on the shaft carries a valve operator 97 operatively connected with the plunger of the valve 68 by a rod 98.

Hand levers 99 and 100 are secured to the shaft and sleeve, respectively, for manually rotating them to operate the valves. The two hand levers are normally locked together for unitary operation by suitable latching means adapted to be released by a releasing lever 101 mounted on the lever 99. Thus the two valve operators may be actuated as a unit or separately, as desired, to control the starting and stopping of the machine.

Means is also provided for actuating the valve operators in response to the spindle carriage being raised to its uppermost limit. To this end, the shaft 92 carries an arm 102 adapted to cooperate with a cam 103 mounted on the carriage base 13. The cam is formed with an inclined surface operative in the upward movement of the carriage to cam the arm 102 outwardly. Thus the shaft 92 and sleeve 96, which is connected thereto by the locked hand levers, together with their respective valve operators, are shifted to valve closing position thereby stopping the rotation and reciprocation of the tool spindle 15.

Reciprocation of the spindle carriage is controlled by a skip-stop mechanism operating in conjunction with the pilot valve 71 and an automatic stroke counter, generally designated by the reference character 104, cooperating with the skip-stop mechanism. By reason of the improved arrangement and interconnection of the mechanism and the counter, the number of separate parts required is reduced to a minimum, construction is materially simplified, and a compact assembly adapted to be entirely enclosed in the frame of the machine is obtained.

Referring to Figs. 3 and 4, the skip-stop mechanism includes a control rod 105 disposed within the hollow column 7 and extending parallel to the axis of movement of the spindle carriage 12. The control rod has sliding bearing supports at opposite ends, one support comprising a bushing 106 with which the rod has a splined connection. The bushing is rotatably supported by a bracket 107 on the interior wall of the column 7 and has a laterally extending crank arm 106^a by which it may be rotated as will appear presently. With this arrangement, the control rod is freely movable endwise in the bushing 106 but is constrained to move with the bushing when the same is rotated.

Mounted at spaced points on the control rod 105 are a pair of limit stops 108 (see Fig. 3) and 108^a (see Fig. 4) of generally disk shaped form, which are preferably set to define the extreme limits of spindle carriage movement, that is, the limits of the tool stroke. An intermediate stop 109 such as that shown in my prior Patent No. 1,945,045, above referred to, is provided, this stop

having a yieldable arm 110 to provide for one-way operation. The stop 109 may be set in the usual manner to define, with the stop 108^a the limits of the working stroke of the tool.

As herein shown, the stops 108, 108^a and 109 are positioned for engagement by an actuating arm 111 secured to the base 13 of the spindle carriage and projecting rearwardly therefrom through a vertical slot 112 in the face of the column 7. The arm 111, on engaging a stop, is effective to shift the control rod in the direction of movement of the spindle carriage and, through the medium of appropriate actuating mechanism, operate the pilot valve 71 and the stroke counter 104.

The intermediate stop 109 is so constructed that, when the control rod 105 is rotated out of its normal position, the arm 110 is withdrawn from the path of the actuating arm 111 thereby permitting the spindle carriage to continue its upward travel until the actuating arm engages the limit stop 108 whereupon the machine is stopped in the usual manner. Rotation of the control rod is effected either manually through the medium of a hand lever 113 or automatically by a solenoid 114 (see Figs. 3 and 5) operatively connected with the arm 106^a of the sleeve 106.

Referring more particularly to Figs. 3 and 5, it will be observed that the hand lever 113 is slidably supported for endwise movement in an elongated bearing 115 formed in the wall of a housing 116 secured to a side wall of the column 7. The inner end of the lever is connected by a link 117 with one arm of a bell crank lever 118 pivotally supported in the housing. The solenoid 114 is supported in the casing opposite the hand lever and its armature 119 is connected to the arm of the bell crank lever in common with the hand lever whereby the bell crank lever may be rocked about its pivot by the energization of the solenoid.

A connecting rod 119^a (Fig. 3) connects the other arm of the bell crank lever 118 with the crank arm 106^a so that the bushing 106 and control rod 105 are rotated out of normal position when the bell crank lever is rocked either by the manipulation of the hand lever 113 or by the energization of the solenoid 114. The control rod is automatically returned to normal position and maintained therein by a compression spring 120 which encircles the connecting rod 119^a with its opposite ends bearing, respectively, against the wall of the casing 116 and a collar 121 fast on the connecting rod.

The actuating mechanism for the stroke counter and pilot valve includes a rock shaft 122 located to the rear of and extending transversely of the control rod 105. The rock shaft is journaled in an elongated bearing 123 carried by a frame 124 mounted on the interior wall of the column 7, the frame also providing a support for the stroke counter 104 and associated apparatus (See Fig. 4.)

Fast on the inner end of the rock shaft 122 is a double armed lever 125. One arm of the lever is disposed between a pair of spaced collars 126 fast on the control rod 105 whereby the lever and the shaft 122 are rocked incident to the shifting of the control rod. The other arm of the lever is connected by means of a link 127 with a counter operating bar 128 slidably supported in spaced bearings 129 carried by the frame 124.

The bar 128 is arranged to operate a mechanical counter or register 130 which may be of any suitable type such as the counter shown in my prior Patent No. 1,945,045 granted January 30,

1934. Each stroke of the spindle carriage, represented by one of the movements of the control rod 105, is registered on the counter and, after accumulating a predetermined number of strokes, the counter operates to complete an energizing circuit for the solenoid 114 in the usual manner. In this way, the reciprocation of the spindle carriage is interrupted automatically and the carriage and honing tool are automatically withdrawn to starting position.

The return of the spindle carriage to starting position automatically resets the counter 130 through the medium of resetting means such as that disclosed in my prior Patent No. 1,945,045, including a rod 131 (see Figs. 3 and 4) slidably mounted for vertical reciprocation at one side of the control rod 105. The rod 131 carries on its upper end a collar or stop 132 engageable by an auxiliary arm 133 secured to the actuating arm 111 of the spindle carriage which moves the rod 131 into its upper position and holds it there when the carriage returns to starting position. The rod is provided on its lower end with a toothed rack meshing with a resetting pinion 134 forming a part of the counter. The counter is thus automatically conditioned for controlling the next operating cycle of the machine in response to the return of the spindle carriage to starting position.

Referring now to Figs. 3 and 5, it will be observed that the end of the rock shaft 122 opposite the end carrying the lever 125 extends into the housing 116 and has secured to it a double armed lever 135. One arm of the lever 135 is connected by a link 136 with a pilot valve operator 137 which is operative to set the pilot valve in either of its two positions. Thus when the control rod 105 is shifted upwardly, the shaft 122 is rocked in a clockwise direction as viewed in Fig. 5 and the valve operator is shifted to the right to set the pilot valve in the position shown in Fig. 7 of the drawings. Upon movement of the control rod and rock shaft in the opposite direction, the valve operator is moved to the left to reverse the pilot valve.

Manual operation of the pilot valve is effected by means of a hand lever 138 slidably supported for endwise movement in a bearing 139 formed on the wall of the casing 116. The hand lever has a pin and slot connection 140 with the other arm of the lever 135, this connection permitting actuation of the pilot valve 71 by appropriate movement of the hand lever without requiring the hand lever to follow each movement of the lever 135 when the valve is operated under control of the skip-stop mechanism.

The operation of the machine may be summarized briefly as follows: It may be assumed that the cylinder to be finished has been loaded on the work table 9 and alined for proper engagement with the hone carried by the spindle 15, the hone, of course, being in withdrawn or starting position at this time. The hydraulic motor 30 is then adjusted by means of the handwheel 49 so that it will rotate the spindle 15 and honing tool at the desired rate as determined by the size of the cylinder and the material from which it is constructed. The pump 52 is also adjusted by means of the handwheel 88 to coordinate the reciprocal speed of the hone with its rotative speed.

Having made the necessary speed adjustments, the machine is started in operation by unlatching the levers 99 and 100 and moving the latter toward the machine. Control valve 68 is thus set in the running position and pressure fluid from 75

the pump 52 is supplied to the upper end of the cylinder 27 causing the spindle carriage to advance the hone into engagement with the work. The spindle rotating motor may be started in operation as soon as the spindle carriage moves out of starting position by moving the lever 99 until it again registers with and locks to the lever 100.

In the downward movement of the spindle carriage, the actuating arm 111 passes over the intermediate stop 109 without shifting the control rod, movement of the carriage continuing until the actuator engages the limit stop 108^a. This shifts the control rod and thereby operates the pilot valve 71 which in turn operates the reversing valve 73 to effect a reversal of the supply of pressure fluid to the carriage reciprocating cylinder 27. The carriage is therefore moved upwardly until the actuating arm engages the intermediate stop 109 and shifts the control rod to its alternate position operating the pilot valve to again reverse the movement of the spindle carriage.

Reciprocation of the spindle carriage within the operating range defined by the stops 109 and 108^a continues until the stop 109 is moved out of the path of the actuating arm 111 either by the manual operation of the hand lever 113 or by the energization of the solenoid 114 through the action of the stroke counter 104. The carriage is then permitted to move upwardly until the cam 103 engages the arm 102 to return the control levers 99 and 100 to their initial position whereby the control valves 60 and 68 are closed. In the return of the carriage to starting position, the actuating arm 111 engages the stop 108 and reverses the pilot valve 71 so that, when the machine is again started, the carriage will be given a downward movement.

If the next cylinder to be operated on by the machine is of different size or of different material than the preceding cylinder, the speed of the hydraulic motor 30 and output of the pump 52 may be adjusted to provide the exact rotative and reciprocal hone speeds required for this particular cylinder. The adjustment is quickly and accurately effected by simply turning the hand-wheels 49 and 88.

It will be apparent from the foregoing that I have provided an improved honing machine of simple and rugged construction in which the controls are arranged in a compact assembly and completely enclosed in the frame of the machine. The machine has a wide range of adaptability whereby cylinders of widely varying sizes and of different materials may be finished accurately and efficiently. By utilizing hydraulic driving mechanism both for rotating and reciprocating the tool spindle, the rotative and reciprocal speeds of the spindle can be varied in incremental steps to enable the honing tool to operate with maximum efficiency regardless of the cylinder being operated on. The rotative and reciprocal speeds of the hone can be accurately coordinated to produce the most satisfactory surface finish on different types of work. Moreover, the hone may be reciprocated rapidly without shock or vibration and with substantially uniform stroking.

I claim as my invention:

1. A honing machine having, in combination, a work supporting table, a reciprocatory carriage supported for movement toward or from said table, a tool spindle adapted to carry a honing tool for operating on work supported on said table, said spindle being rotatably supported on

said carriage and reciprocable therewith, and hydraulic means for rotating said spindle and for reciprocating said carriage in predetermined timed relation thereto to enable the tool to operate upon the work with maximum efficiency, said hydraulic means comprising a variable speed rotary hydraulic motor for rotating the spindle, a reciprocatory hydraulic motor for reciprocating the carriage, means for varying the operating speeds of said motors, manually controlled means for starting said motors independently of said speed controlling means, and automatically operated means for stopping both of said motors simultaneously.

2. In a honing machine, in combination, a hollow upright column having an elongated slot formed vertically in the face thereof, a reciprocatory carriage supported on the face of said column, a rigid arm secured to said carriage and projecting rearwardly therefrom into said column through said slot, pressure fluid operated means for imparting continuous reciprocatory movement to said carriage, valve means controlling said pressure fluid means to limit the range of movement of said carriage, a control rod slidably supported for endwise movement in said column rearwardly of said slot and extending substantially parallel to the axis of movement of said carriage, a pair of stop members mounted on said control rod in position respectively to engage said arm as the carriage approaches the limits of its travel whereby the rod is alternately moved in opposite directions, and means enclosed within said column operatively connecting said rod with said valve means to enable the rod to control the valve incident to its movements by said arm.

3. In a honing machine, in combination, a hollow upright column, a reciprocatory carriage supported on the face of said column, an elongated slot in the face of the column extending parallel to the path of movement of said carriage, a rigid arm secured to said carriage and projecting rearwardly therefrom into said column through said slot, pressure fluid operated means for imparting continuous reciprocatory movement to said carriage, valve means enclosed in said column operative to control said pressure fluid means to limit the range of movement of said carriage, a control rod rotatably and slidably supported for endwise movement in said column rearwardly of said slot and extending substantially parallel to the axis of movement of said carriage, a pair of stop members mounted on said control rod in position respectively to engage said arm as the carriage approaches the extreme limits of its travel whereby the rod is moved endwise in the direction of movement of the carriage, an intermediate stop mounted on said control rod adapted to be selectively moved by rotation of the rod into and out of position to operatively engage said arm, mechanism adapted to count the strokes of said carriage and operative to automatically control the rotation of said rod, and common means controlled by said rod in its movement by said arm for operating said valve means and said counting mechanism.

4. In a honing machine, in combination, an upright column, a reciprocatory carriage, a tool spindle rotatably supported on said carriage and reciprocable therewith, means for rotating said spindle including a motor supported on said column and a drive shaft operatively connecting the motor with the spindle, said shaft being disposed laterally of the axis of the spindle and

carriage and extending generally parallel to the reciprocatory path of the carriage, and means supporting said carriage for reciprocation on said column effective to counteract the torque exerted on the carriage by said shaft incident to the rotation of the spindle, said supporting means comprising a pair of vertically disposed cylindrical guide bars mounted on the column in parallel spaced relation, and a plurality of roller members mounted at substantially spaced points on opposite sides of said carriage and engageable with the respective guide bars to prevent lateral movements of the carriage while permitting free reciprocatory movement thereof.

5. In a honing machine, in combination, an upright column, a tool spindle carriage adapted to be reciprocated relative to said column in a substantially vertical plane, means for reciprocating the carriage, counterbalancing means operative to exert a force tending to move the carriage upwardly to counterbalance the weight thereof, said counterbalancing means having an off-center connection with the carriage, and means for supporting said carriage for reciprocation and for preventing the carriage from jamming due to the application of the counterbalancing force at an off-center point on the carriage, said supporting means comprising a pair of vertically disposed cylindrical guide bars mounted on the column in parallel spaced relation and a plurality of roller members mounted at substantially spaced points on opposite sides of said carriage and operatively engageable with said guide bars.

6. In a honing machine, in combination, an upright column, a tool spindle carriage adapted to be reciprocated relative to said column in a substantially vertical plane, means for reciprocating the carriage, counterbalancing means operative to exert a force tending to move the carriage upwardly to counterbalance the weight thereof, said counterbalancing means including a pneumatic cylinder and piston mounted above the carriage, said cylinder being arranged with its axis parallel to the reciprocatory path of the carriage and said piston being operatively connected to the carriage at a point spaced laterally of the axial center of the carriage, and means supporting said carriage for reciprocation and for counteracting the effect of the off-center connection of said counterbalancing piston, said supporting means comprising a pair of vertically disposed cylindrical guide bars mounted on said column in parallel spaced relation and a plurality of roller members mounted at opposite sides of the carriage and substantially spaced apart in the direction of carriage movement, said roller members operatively engaging the respective guide bars to prevent lateral movements of the carriage while permitting the same to reciprocate freely on the bars.

7. A honing machine having, in combination, a hollow upright column, a work supporting table mounted on the face of the column, a reciprocatory carriage supported on the face of the column for movement toward and from said table, a spindle adapted to carry a honing tool for operating

on work supported on the table, said spindle being rotatably supported on said carriage and reciprocable therewith, a head mounted at the top of said column, means for reciprocating said carriage comprising a cylinder disposed in said head above said carriage with its axis extending substantially parallel to the reciprocatory path of the carriage, a piston reciprocable in said cylinder and operatively connected with the carriage, means for rotating said spindle simultaneously with the reciprocation of said carriage comprising a rotary hydraulic motor enclosed in said head and drivingly connected with said spindle, pressure fluid pumps for supplying pressure fluid to said cylinder and said hydraulic motor, an electric motor for driving said pumps, and means for supporting said electric motor whereby a minimum of the motor vibration is transmitted to said column and the elements supported thereon comprising a bracket mounted on said column closely adjacent the base thereof.

8. In a honing machine having, in combination, an upright column, a work supporting table mounted on the face of the column, a reciprocatory carriage supported on the face of the column for movement toward and from said table, a spindle adapted to carry a honing tool for operating on work supported on said table, said spindle being rotatably supported on said carriage and reciprocable therewith, means for reciprocating said carriage comprising a piston operatively connected with the carriage and operating in a cylinder mounted at the top of said column, a rotary hydraulic motor mounted at the top of said column, means connecting said spindle for rotation by said motor comprising a shaft driven by the motor extending substantially parallel to the axis of the spindle and drivingly connected therewith at a point below said cylinder, pressure fluid pumps for supplying pressure fluid to said hydraulic motor and said cylinder to rotate and reciprocate the spindle, an electric motor for driving said pumps, and means for supporting said electric motor on said column so as to minimize vibration of the machine comprising a supporting member mounted on the column closely adjacent the base thereof.

9. A honing machine comprising, in combination, an upright column, a work supporting table mounted at one side of said column, a reciprocating carriage supported on the column for movement toward and from said table, a tool carrying spindle rotatably supported on said carriage and reciprocable therewith for operating on work supported on said table, hydraulically operated carriage reciprocating means supported adjacent the top of said column, hydraulically operated spindle rotating means also supported adjacent the top of said column, means for supplying pressure fluid to said hydraulically operated means, an electric motor for operating said pressure fluid supply means, and means for supporting said electric motor and said pressure fluid supply means adjacent the base of said column to minimize vibration of the machine.

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