

Nov. 2, 1943.

H. ERNST ET AL
SURFACE FINISHING MACHINERY

2,333,304

Filed Jan. 25, 1940

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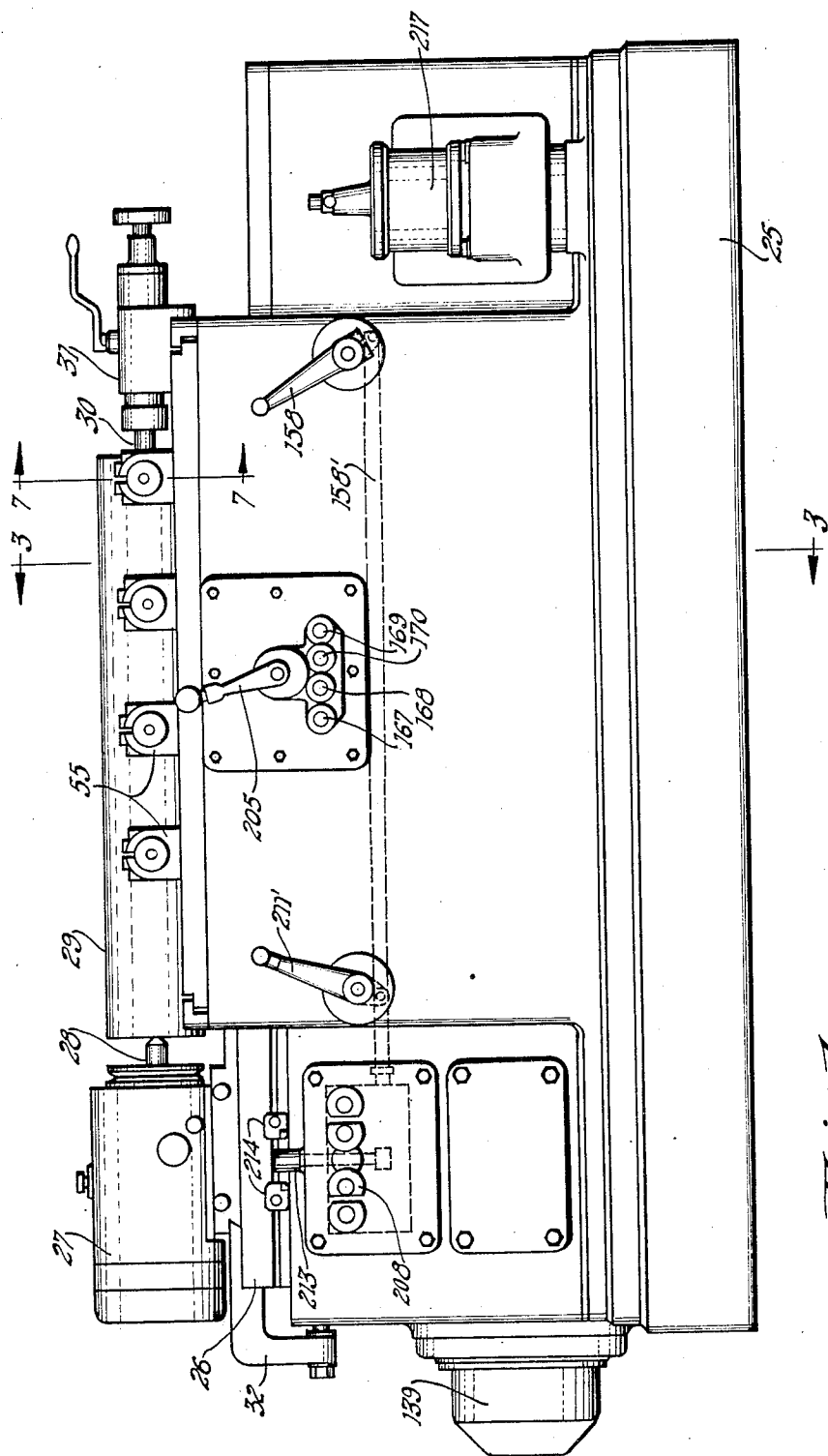


Fig. 1

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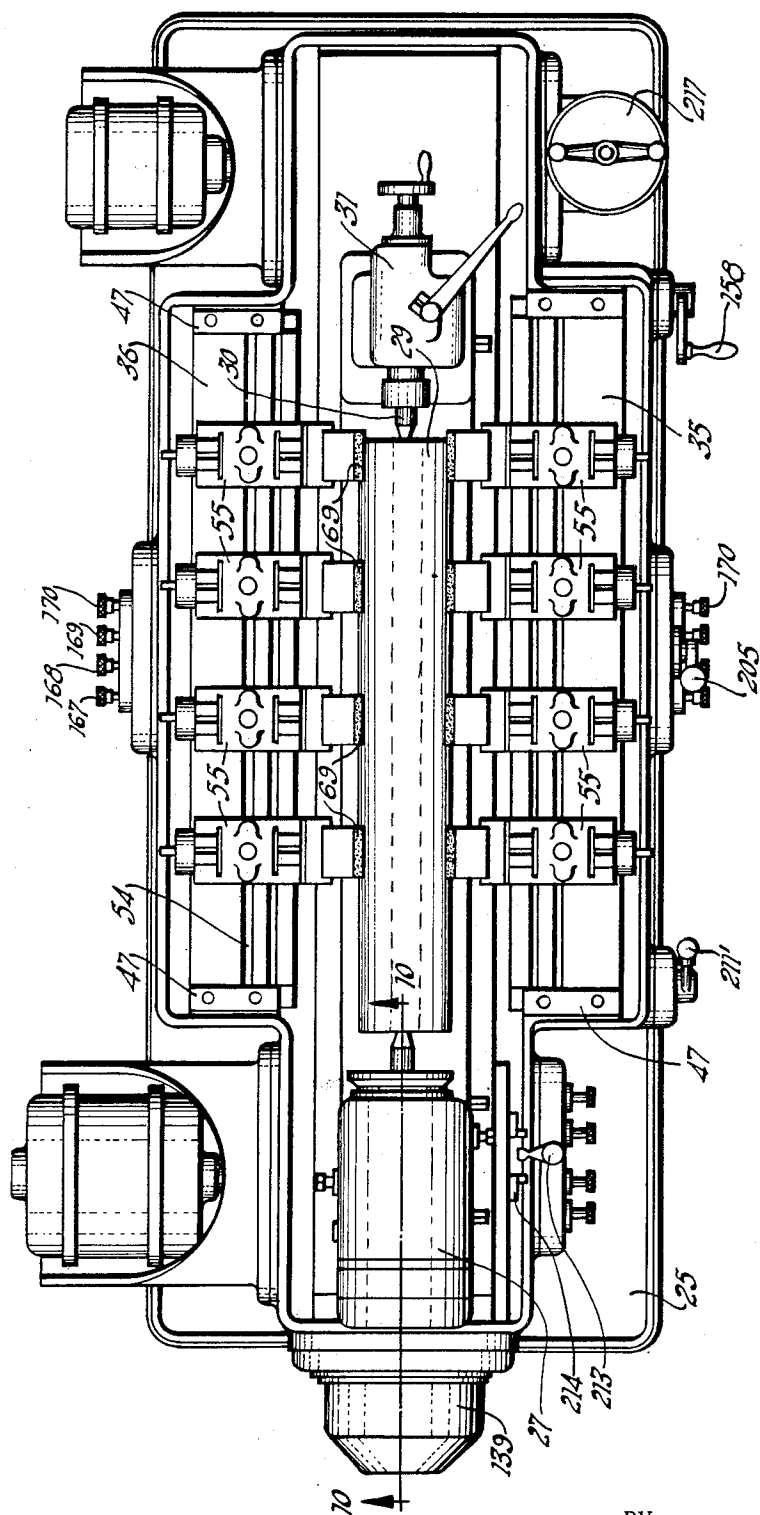


Fig. 2

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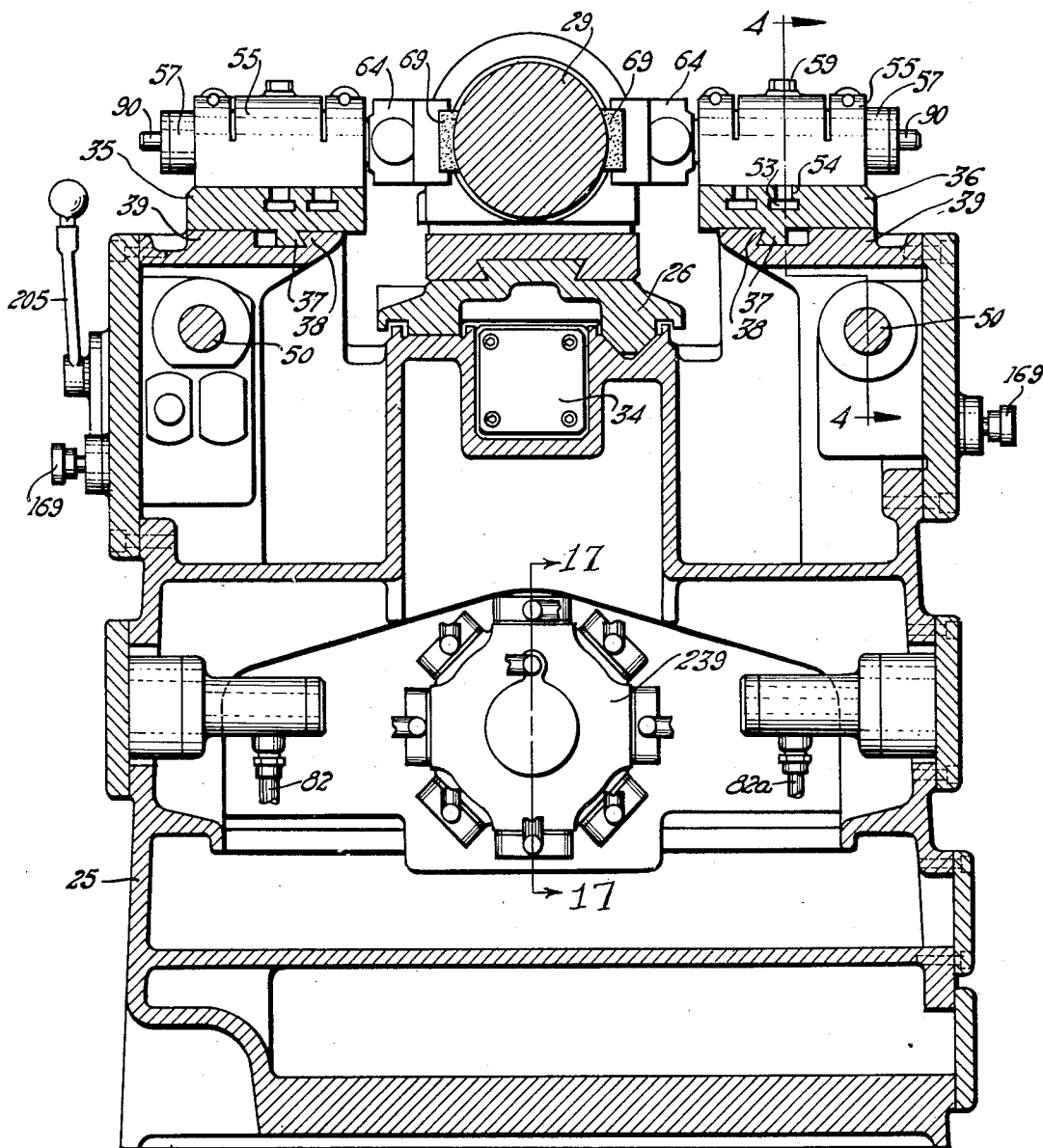


Fig. 3

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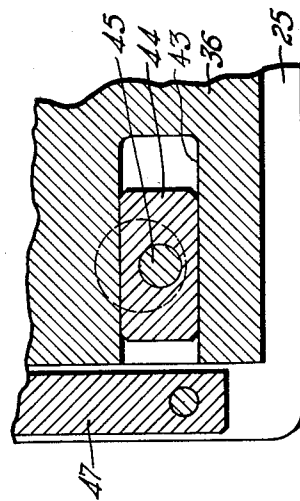
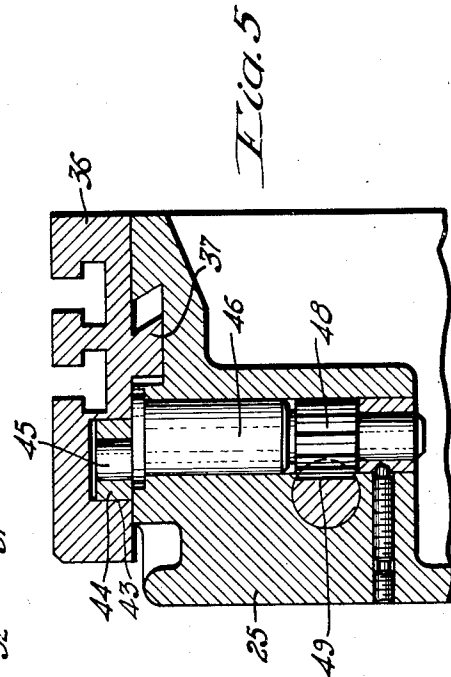
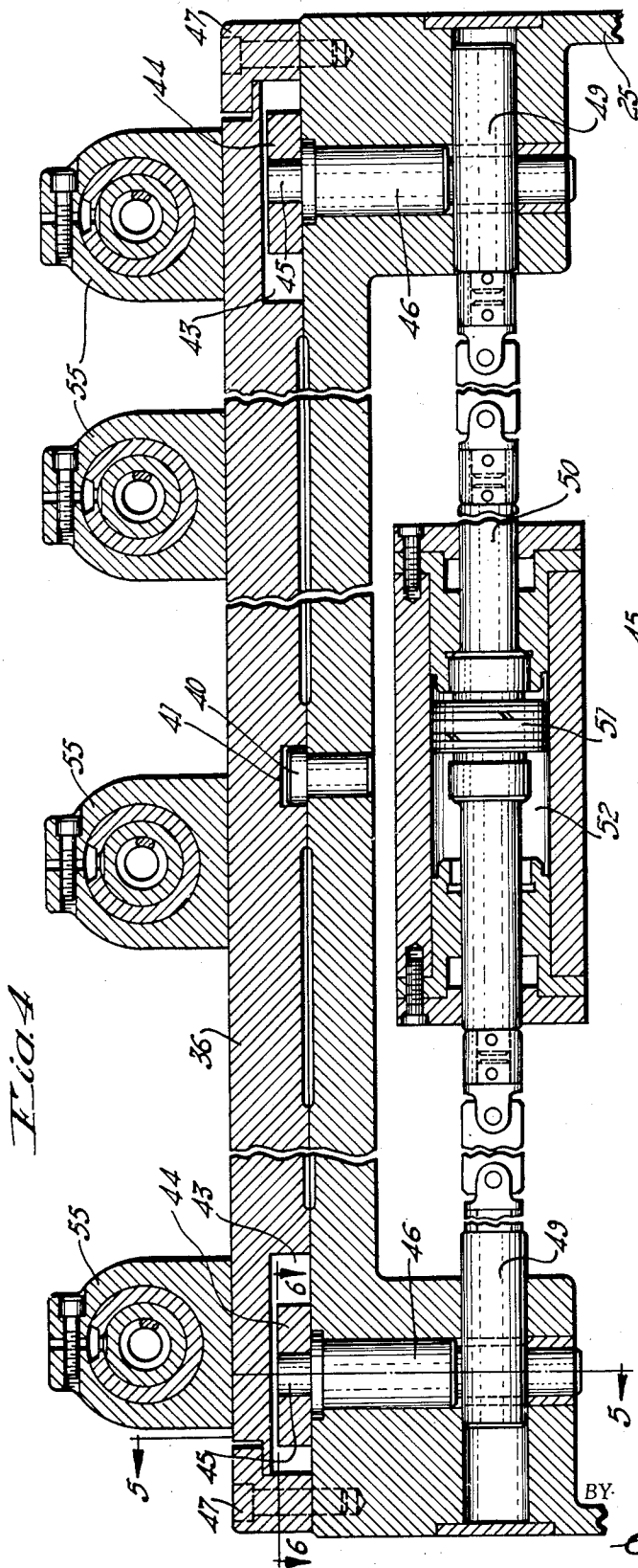
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Fig. 7

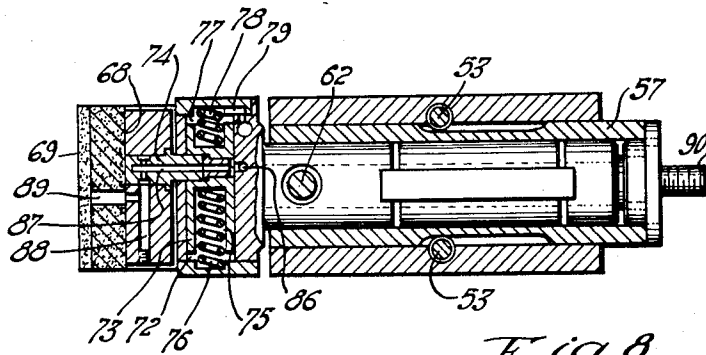
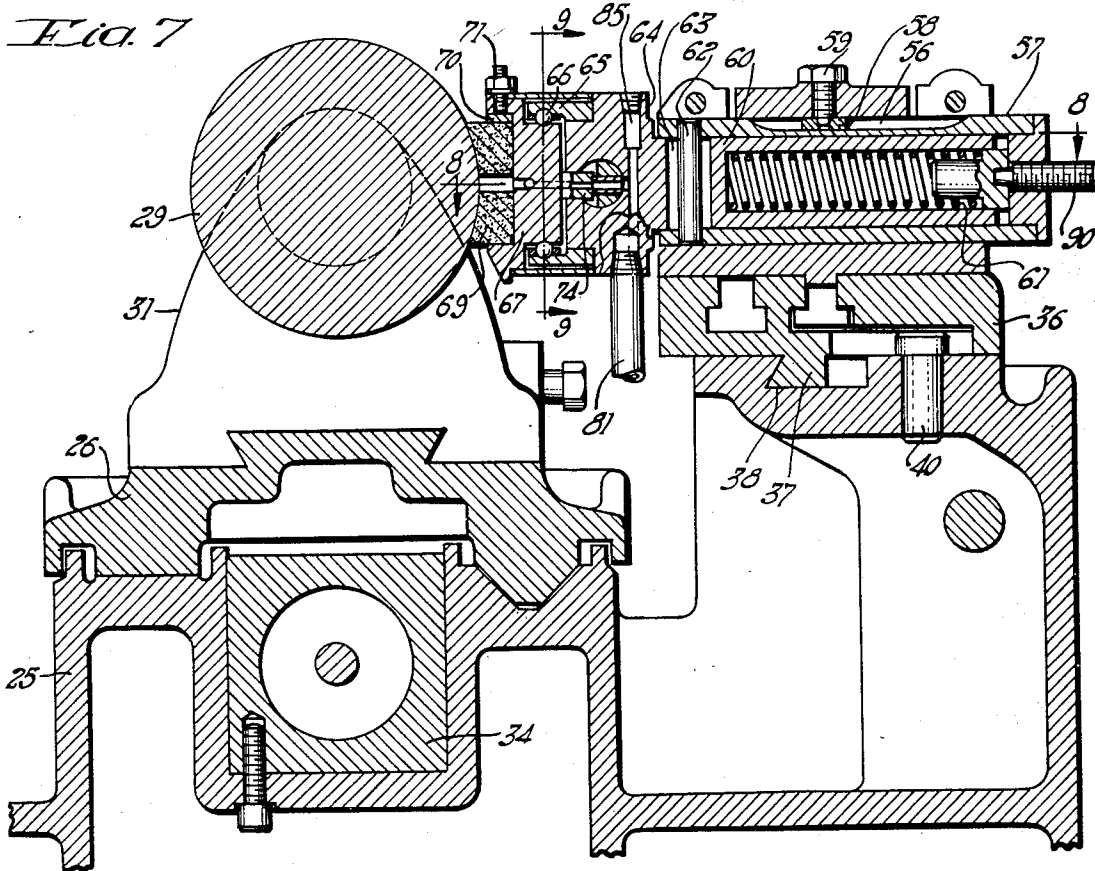


Fig. 8

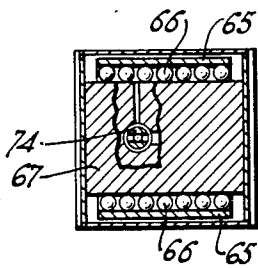


Fig. 9

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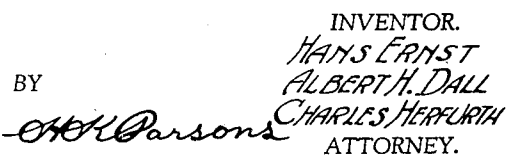
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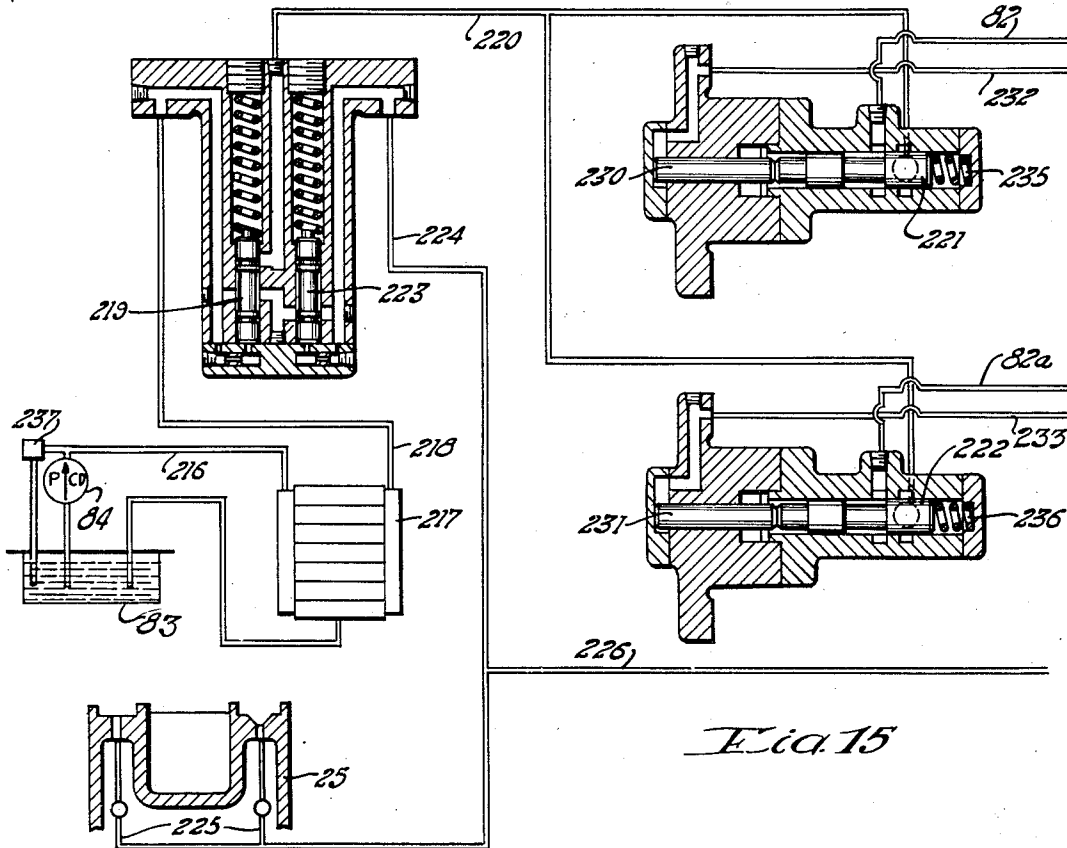


Fig. 15

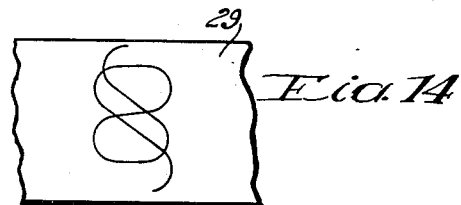


Fig. 14

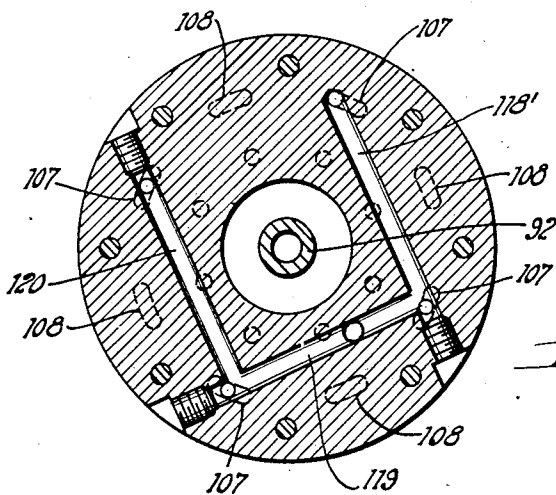


Fig. 13

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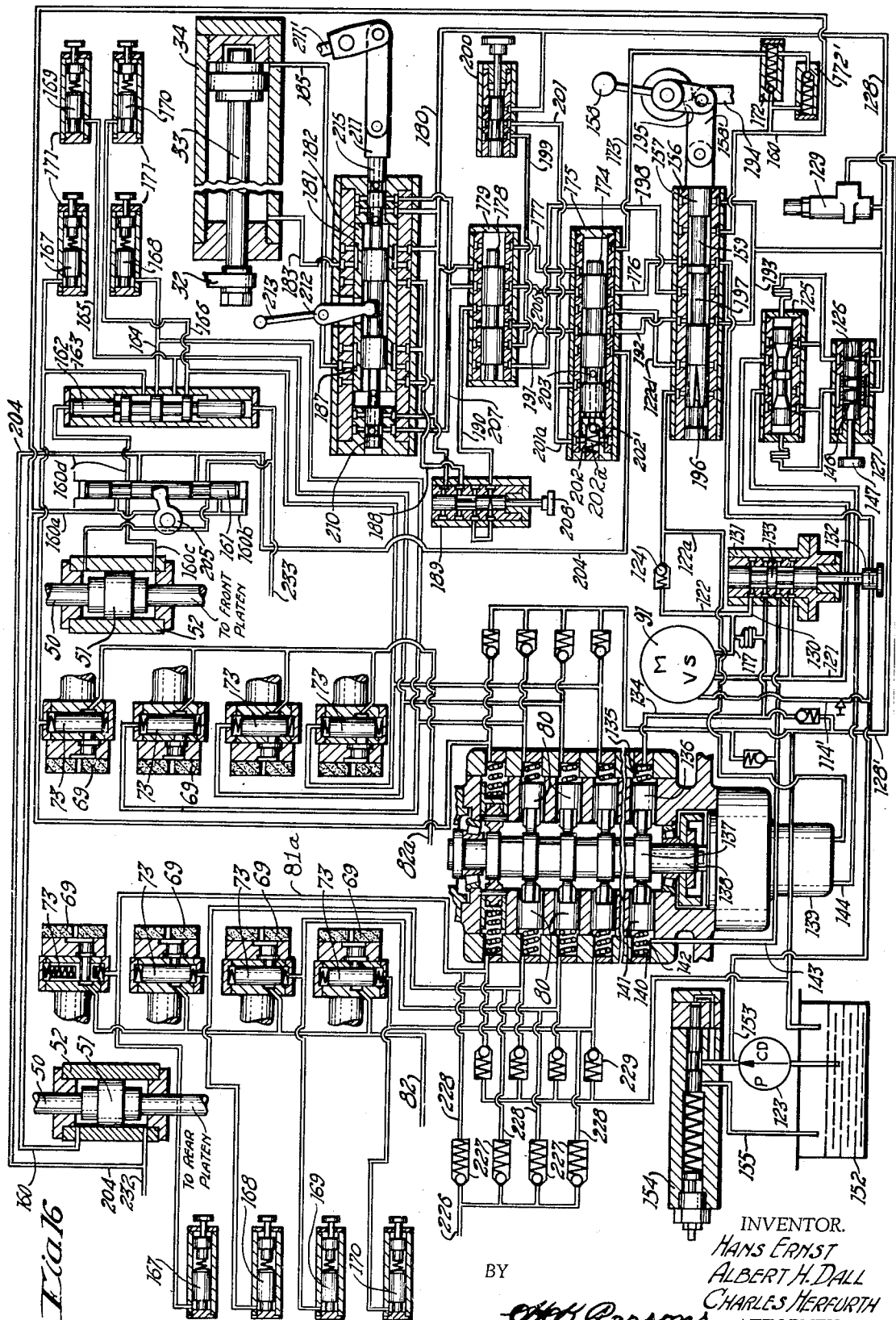
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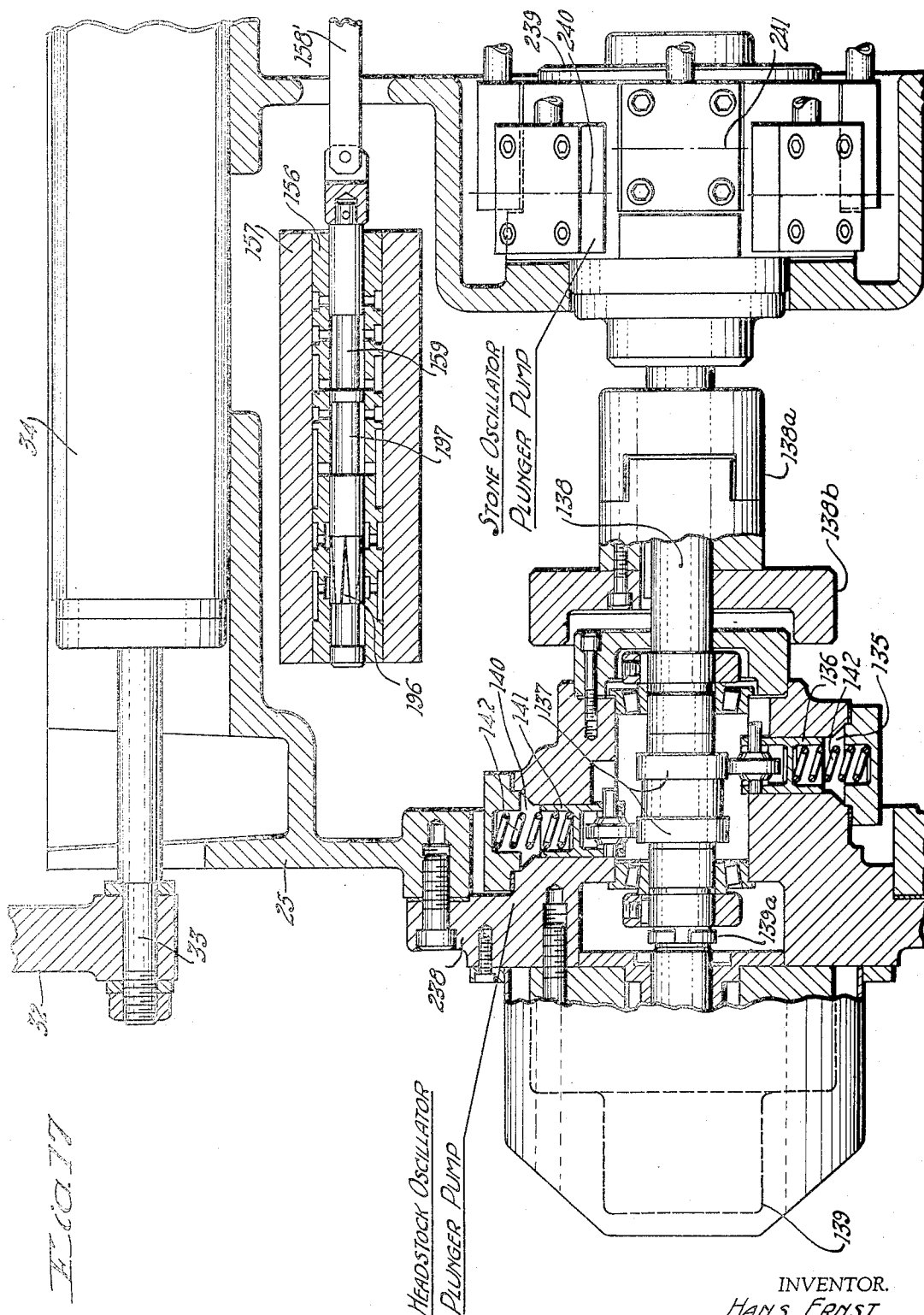
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SURFACE FINISHING MACHINERY

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9 Sheets-Sheet 9



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2,333,304

SURFACE FINISHING MACHINERY

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Application January 25, 1940, Serial No. 315,510

36 Claims. (Cl. 51—67)

This invention relates to improvements in surface finishing machinery and has particular reference to improvements in machines intended for producing a final surface finish of high degree of accuracy, particularly on metal articles of substantially circular form in cross section.

The initial machining of such articles or work pieces in its final stages is normally effected as a grinding operation, although in some instances the present invention is utilizable directly to produce a finished surface on an article previously shaped as by turning, broaching or the like.

In the initial formation of the work piece by turning or broaching, the previously operative tools normally effect a certain tearing and grooving of the material; likewise, ordinary grinding operations—even with the use of extremely fine grit abrading members—due to the nature of the grinding operation and the necessary relative speeds of tool and work, produce minute hills and valleys, grooves or scratches in the work piece which under high magnification can be readily noted as a roughness or irregular nap of upstanding material circumscribing the work piece.

It is, therefore, one of the principal objects of the present invention to provide a machine which will effect, through cold cutting a maximum abrading action of a character to remove this nap or other irregularities resulting from the previous machining operation.

A further object of the present invention is the provision of a machine capable of effecting multiple relative movements of an abrading member or members and the surface of the work to prevent repetitious engagement between corresponding portions of the abrading member and work which might otherwise result in reproduction or perpetuation of certain of the surface scratches or irregularities.

A further object of the present invention is the provision of an improved machine, particularly adapted for operation upon cylindrical or other work pieces of circular or substantially circular form in cross section which will effect a relative multi-directional scrubbing motion in constantly changing direction between the tool and work piece whereby to eliminate visible scratches and hill and valley effects on the surface of the work piece.

An additional object of the present invention is the provision of a machine having the capacity for effecting relative rotary and oscillatory movements of the interengaged tool and work

piece elements in a smooth manner, while effecting an appreciable rate of cut speed resultant from said movements.

Additionally, the present invention contemplates the provision of an improved machine capable of alternative employment for either ultimate finishing or combined roughing and finishing operations in which the several parts shall be capable of ready relative adjustment to accommodate varying lengths and diameters of work pieces or portions of work pieces to be individually or simultaneously operated upon and in which the series of tool holding elements may be satisfactorily controlled individually and selectively or in unitary groups.

Other objects and advantages of the present invention should be readily apparent by reference to the following specification, considered in conjunction with the appended drawings illustrating one embodiment of the principles thereof, and it will be understood that any modifications or variations may be made in the specific structural details and combination of elements hereinafter described within the scope of the appended claims without departing from or exceeding the spirit of the invention.

Figure 1 represents a front elevation of a machine constructed in accordance with and embodying the principles of the present invention. Figure 2 is a top plan view thereof.

Figure 3 is a vertical sectional view taken as on the line 3—3 of Figure 1.

Figure 4 is an enlarged vertical section on the line 4—4 of Figure 3.

Figure 5 is a vertical section as on line 5—5 of Figure 4.

Figure 6 is a fragmentary transverse section as on line 6—6 of Figure 4.

Figure 7 is a vertical section through one of the tool holding elements and related parts of the machine as on the line 7—7 of Figure 1.

Figure 8 is a sectional view through the tool mechanism at right angles to Figure 7 as on the line 8—8 thereof.

Figure 9 is a section with parts broken away as on the line 9—9 of Figure 7.

Figure 10 is a vertical sectional view as on the line 10—10 of Figure 2.

Figure 11 is a vertical section through the head stock driving motor as on the line 11—11 of Figure 10.

Figure 12 is a similar view largely in section, illustrating the interporting connections for supply and exhaust of actuating medium as respects the chambers and rotary valves of the motor.

Figure 13 is a similar view illustrating the interporting of a different series of conduits of the headstock motor.

Figure 14 is a fragmentary diagrammatic view of one preferred path of relative movement between an individual abrasive particle or point on the tool and the work surface being operated upon thereby.

Figure 15 is a diagrammatic view of a portion of the pump circuit and controls for effecting lubrication of certain parts of the machine and supply of lubricant to the work piece and tools, and

Figure 16 is a diagrammatic view of the additional pump mechanisms and remainder of the hydraulic actuation and control system of the machine.

Figure 17 is a vertical sectional view through the oscillation pumps as on the line 17-17 of Figure 3.

The machine chosen for purposes of illustration comprises a bed or support 25 having mounted thereon a longitudinally traversable table 26 on which is suitably adjustably mounted the headstock unit 27 having a driving spindle 28 for engagement with the work piece 29, whose other end is supported by the center 30 of the adjustable tailstock mechanism 31.

Depending from the table 26 is a bracket 32 connected to piston rod 33 (Figure 17) of the reciprocating hydraulic motor 34 controllable as hereinafter described for effecting longitudinal reciprocations of the table and work piece supported thereon.

Mounted on the bed at each side of the work piece are the platens 35 and 36 of similar oppositely arranged form, having the depending dovetail lugs 37 interengageable with the dovetail ways 38 of brackets 39 on the bed.

A central guide pin 40, particularly illustrated in Figures 4 and 7 of the drawings, has a head portion slidably engaged in groove 41 of the platen, permitting of in and out movement of the latter but restraining same against shifting longitudinally with respect to the supporting bracket 39. The platens 35 and 36 are each formed with recesses 43 receiving slide blocks 44 actuatable by eccentric pins 45 on the stub shafts 46 which are disposed in pairs—one near each end of the platen.

Guide brackets 47 guide the platen for in and out movement, while preventing tilting or twisting thereof. Members 48 extend downwardly from the bracket support 39 and have secured or formed thereon pinions 48' (Figure 5) engaged by rack portions 49 of the double end piston rod 50 having a piston portion 51 reciprocable in cylinder 52.

By reference particularly to Figures 4 to 6 inclusive it will be readily understood that reciprocation of the piston will move the racks 49 in one direction or the other, correspondingly oscillating members 48 to displace blocks 44 either inwardly or outwardly, and thus effect corresponding shifting of the associated platen 35.

These platens have adjustably supported thereon as by clamp bolts 53 selectively engageable longitudinally and transversely in the T-slots 54, the tool holders 55 particularly illustrated in Figures 7 and 8. These, it will be noted, are preferably of multiple number—eight being shown, each unit being complete in itself for operation on a selected portion of the work piece while the series of units are jointly actuated

and controlled by the hereinafter described hydraulic mechanism of the machine.

Each individual holder comprises the exterior or bracket portion 55 having a bore 56 slidably receiving the sleeve or bushing 57 keyed as at 58 against rotative movement, suitable means such as clamp screw 59 being provided for securing the member 57 in longitudinally adjusted position.

Slidable within member 57 is a second sleeve 60 enclosing spring 61 effective to urge the sleeve toward the work to a limit determined by pin 62 carried by sleeve 57 and extending transversely of slot 63 in the sliding member 60. The inner portion of the tool holder sleeve is provided with a head 64 having ways 65 for the anti-friction bearings 66 mounting block 67 for transverse reciprocation. Block 67 has a seat or socket 68 to receive the abrasive tool 69 in the form of an extremely fine abrasive block or stick. An adjustable gib 70 clamped as by screw 71 serves rigidly to secure the abrading member within the seat.

Formed in the head 64, extending parallel with the ways 65, is a cylindrical bore or motor chamber 72 in which is slidable the piston 73 interengaged by stud 74 with the abrasive holder 67. The piston has a recess 75 at one end to receive the elongated actuating spring 76 and at the other end has a second recess 77 containing a buffer spring 78. A passage 79 communicating with the chamber 77 serves to transmit actuating fluid pulsations from one of the pistons 80 shown in Figure 16 to react on the piston 73. As a pulsation of the hydraulic actuating medium is forced into this end of cylinder 72, the piston 73 will be forced downwardly as viewed in Figure 8 against the resistance of spring 76, while as the pressure pulsation is released the spring will expand, moving the piston in the opposite direction, its reverse movement being yieldingly restrained by the buffer spring 78.

It will thus be noted that in addition to their individual positional adjustments the series of tools and holders therefor respectively at the front and the rear of the machine are each adjustable as a group in a direction toward and away from the interposed work piece 29, and are also individually, yieldingly urged into operative engagement with the work piece as well as supported for individual reciprocating movements in a direction parallel with the axis of the work piece.

For most satisfactory finishing it is ordinarily desirable that a cutting medium or oil be constantly supplied in a manner tending to produce an interposed film between the work and operative surface of the tool. This is effectable, for example, by coupling to each of the heads 64 a flexible conduit 81 connected to supply line 82 of the cutting fluid and lubrication circulating system, Figure 15, which includes reservoir 83 and pressure pump 84 for effecting circulation of the medium. This conduit is connected by the interdrilled passage 85 to port 86 of the cutting fluid transmitting passage 87 formed in stud 74 and thence distributed through passage 88 and aperture 89 in the face of the abrading member to the surface of the work at a point centrally of the engagement of the abrading member therewith.

The pressure exerted by spring 61 for forcing the abrading member into engagement with the work is adjustable as by screw 90. As the abrading member wears down the high spots on the

work surface and the surface approaches smoothness, dynamic conditions created by the relative movement of the abrading member with respect to the work piece generate fluid film pressures which tend to separate the two in a manner similar to a lubricated bearing, thus causing decreased abrading action. Additionally, static fluid pressures can be imposed through aperture 89 to the abrading surface, thus supplementing the generated dynamic pressures and permitting the control of the separation of the abrading member and the work by the operator to suit the conditions of work material and stone action. The application of cutting fluid through the stone has the two-fold purpose of first application of fluid directly at the points of abrasion, and secondly, the application of static fluid pressures at the will of operator to supplement the dynamically generated pressures.

Mention has been made of the fact that the work piece 27 is illustrated as supported for longitudinal shifting movement by table 26 and has coupled therewith a driving spindle 28. To attain most effective results in performance of the finishing operation it has been found desirable to impart to the work, in addition to its longitudinal or axially traversing movement, a compound movement about its axis which can best be defined as a motion of rotation having superimposed thereon a motion of rotary oscillation. This is accomplished by effecting a potential actuation of the headstock motor 91 in a constant direction at a uniform rate of rotation and then providing additional mechanism alternately reacting positively and negatively on this headstock motor to effect successive pulsations of acceleration and deceleration. In this manner a uniform number of revolutions per minute of the work piece is effected but by a back and forth progressively advancing oscillation of the work instead of a constant and uniform rotation thereof, whereby the relative scrubbing action or effective relative movements of the work surface and abrading member is greatly improved and maximum variance in relative directional movements of work surface and individual abrasive particle is attained.

In a preferred form, the frequency ratio between rotary oscillations of the work and longitudinal reciprocations of the abrading member may be two to one and in such a phase relation that a figure eight type of progressively advancing spiral path is traversed by an individual abrasive particle on the surface of the work with constant reversal of effect between the work surface and any of the multiplicity of cutting facets of the abrasive particle. This particular path, effectable by the several potential movements of the parts of the machine at the relative two to one ratio of reciprocations and oscillations above referred to, has been indicated in Figure 14. In an alternative form the frequency ratio may be one to one and the phase difference 90°, thus providing a relative path for the abrasive grain which is generally circular, where the amplitudes are equal, and elliptical where the amplitudes are unequal. In another alternative form the frequency ratio may be slightly less than one to one, thus giving a constantly changing path.

Certain structural details of the headstock motor suitable for effecting the composite movement of the work piece just referred to have been illustrated in Figures 10 to 13 inclusive. From this it will be noted that the driving spindle 28 of the headstock is carried in a main spindle

or shaft 92 suitably supported in anti-friction bearings 93.

Keyed on member 92 is the bushing 94 having suitable splines in interengaged driving relation with the motor body 95. This body has a multiplicity of radial grooves or slots 96 formed therein which, in the present instance, are shown as 14 in number. Slidably engaged in each of these slots is the blade 97 outwardly urged as by springs 98 and having rollers 99 riding on the lobed inner surface of the ring 100. This ring is retained between the end plates 101 and 102 and is preferably symmetrically hollowed to provide the crescent-shaped chambers 103, 104, 105 and 106 into which upon relative rotation of the rotor 95 the several blades 97 are successively forced by their actuating springs 98.

For effecting actuation of the motor body in either direction, there have been provided a first series of circumferentially elongated ports 107, shown as four in number, respectively disposed each at one end of the arcuate chambers 103 while at the opposite end of the chambers are similarly shaped ports 108. The ports 107—as indicated in Figure 10—are coupled by grooves 109 with inner circular ports 110 while the ports 108 are connected by grooves 111 with the inner circular ports 112.

The function of the ports 110 and 112 and the slots 109 and 111 connecting them to the circumferentially elongated slots 107 and 108 is to keep the same pressure on the end of blade 97 which is toward the center and also the roller 99 which bears against the outer end of blade 97.

It is necessary to keep these pressures equal in order not to build up a force at blade 97 against slot 96 which would produce a friction force that would prevent the blade 97 and roller 99 from moving radially when they are passing an exhaust or a pressure port 107 and 108.

Ports 110 and 112 and the connecting slots 109 and 111 also serve as a passageway to permit inlet or outlet of oil under the blades 97 during the time that they are moving radially while the blade and roller are rotating past an exhaust or a pressure port 107 or 108. When the blade 97 and roller 99 rotate to such a position that the end of the pressure or exhaust port 107 and 108 is reached, the ports 110 and 112 are also cut off and the bottoms of the blades 97 are then connected to a new set of ports 112' which are connected to an annular groove 113' which is connected to pump pressure through line 114', Figure 16. Therefore, the blade 97 is maintained in contact with roller 99 and the latter with ring 100 while rotating between the ports 107 and 108 in chambers 103, 104, 105 and 106.

For suitably coupling the conduits for pressure actuating medium with the porting groups 107 and 108, the motor head 101 is provided with multiple interdrilled passages as will be best understood by reference to the sectional views, Figure 12 and Figure 13. Figure 12 has been taken as on the section line 12—12 of Figure 10 and indicates the interconnected passages 113, 114 and 115 communicating as by the passages or drillings indicated at 116 with the series of portings 108. These passages are in turn suitably connected with the supply conduit 117 through passage 118.

A second series of interdrilled passages 118', 119 and 120 formed in the head 101, as shown in Figure 13, connects with the several portings 107 to convey the exhaust actuating fluid from the

motor to discharge conduit 121. It is to be particularly noted that the arrangement of sliding vanes and multiple pressure ports is such that at all times there are one or more vanes in intermediate position within each of the pressure chambers such as 103, 104 in position for reaction thereagainst of the pressure conditions existing in both the portings 107 and 108. It will further be noted that by the combination and arrangement of vanes and pressure chambers shown there will be maximum effective torque reaction of a sensitive character on the shaft 92 for effecting its combined rotary and imposed rotary oscillatory movements and transmitting same to the work in a smooth manner.

For specific understanding of the manner in which these movements are imparted to the work driving motor, attention is invited to the hydraulic circuit diagram as particularly illustrated in Figure 16 of the drawings. There is there shown as coupleable with the hydraulic fluid input line 117, previously referred to, a uniflow pressure line 122 coupled and controlled by valving hereinafter described in detail with the pressure creating pump, 123, a check valve 124 preventing reverse flow of fluid from the pressure supply line. The opposite side of the motor is coupled by conduit 121 with the balancing valve 125 from which it passes through the adjustable throttle portion 126 of valve unit 127 into exhaust conduit 128 having the adjustable back pressure valve 129 for maintaining suitable pressure in the system as an entirety for purposes which will be hereinafter described. Extending from pressure conduit 122 is a conduit 130 leading to the headstock selector valve unit 131, containing a valve member having an actuating portion 132 and a spool 133 which, in the position shown in Figure 16, couples pressure conduit 122 with conduit 134 extending to one of the oscillation control cylinders 135.

It should be stated at this time that the plunger-pump that causes rotary oscillation of the headstock spindle 92, Figure 10, is shown merely diagrammatically on the hydraulic diagram Figure 16.

Instead of only one cylinder 135 and piston 136 and opposing this only one cylinder 140 and piston 141, there are really four cylinders 135 and pistons 136 spaced 90° apart in the right hand plane shown on Figure 17 and four cylinders 140 and pistons 141 spaced 90° apart in the left hand plane shown on Figure 17. Since all four of the cylinders 135 are connected together through interdrilling in the pump body, and also since all four of the cylinders 140 are likewise connected they act hydraulically as one pair of opposed cylinders; that is, one cylinder discharges oil when the opposite one is on the suction stroke.

The exact construction of the headstock oscillator plunger pump as shown on Figure 17 will be explained later. The hydraulic function of this pump is explained as follows:

Mounted in this cylinder 135 is a piston 136 having a follower riding against cam 137 on shaft 138 which is driven by the hydraulic motor 139 which determines control of the various oscillator mechanisms of the present machine. Diametrically opposed to cylinder 135 is a second cylinder 140 having a piston 141 also provided with a follower engaging the cam 137. Springs 162 maintain the pistons in engagement with this cam which is formed with diametrically opposite high and low points so that the pistons

will be shifted alternately and in timed relation in suction and compression strokes. Leading from cylinder 140 is conduit 143 coupled through valve unit 131 with the exhaust conduit 121 of the headstock motor.

The valve 131 serves as a selector to determine whether the headstock motor is driven directly and entirely controlled by the pressure input through 117 and exhaust through 121, which is the condition existing when the valve is in its inwardly pressed position, or whether the headstock is subject to superimposed hydraulic pulsations produced by the oscillator control mechanism when the valve is in the position shown in Figure 16 and the oscillator is connected in parallel with the input and output sides of the motor.

The oscillator motor 139 is itself of conventional type actuated by hydraulic medium supplied from pressure line 122a and exhausted through conduit 144 which is coupled with the opposite side of the balancing valve 125 and passes through the throttle control portion 146 of valve 127 to discharge conduit 128.

As shown, the parts are so related that one-third of the total flow passes through the headstock motor for effecting rotation thereof while two-thirds is directed to the oscillator mechanism for effecting its rotation whereby the oscillator motor will rotate at a much higher rate of speed effecting a multiple number of strokes of the pistons 135—141 for each rotation of the headstock motor. By adjustment of resistances in valve 127 as by rotation of the control knob 147 the relative rotation of the two motors may be suitably controlled and varied.

From the foregoing it will be readily apparent that the input flow through conduit 117 of itself and when the oscillator is short circuited by suitable adjustment of valve 131 serves to impart a constant and uniform rate of rotation to the headstock motor and thus to the work piece. When, however, the oscillator mechanism is coupled in parallel with the drive to the headstock motors, the action of the piston 135 serves alternately to add and subtract to the quantity of liquid in the system on the input side of the hydraulic motor, while action of the piston 141 counteracts the quantitative displacement of fluid on the exhaust side of the motor. As a result, at any period of time the actual movement of the hydraulic motor will be the algebraic sum of the flow of input fluid from pump 123 and the liquid displaced positively or negatively in effect by piston 135. For effective operation the unit displacement of the piston must be greater than the potential flow during such unit of measurement through input line 117. When piston 135 is moving in an inward or suction stroke it will require more fluid than is being supplied to the headstock motor by the pump 123, with the result that the fluid in the system displaced by the outward or pressure stroke of piston 141 will act to rotate the headstock motor in a counterclockwise direction. Upon reversal of strokes of the pistons by rotation of the oscillator motor and cam, the amount displaced by piston 135 will be additive to the amount continuously being supplied through line 117 with the result that the headstock motor will then be rotated at an accelerated speed in a clockwise direction.

It will thus be seen that there is imposed on the headstock motor a movement of simple rotation at a predetermined number of revolutions per minute, together with a movement of super-

imposed rotary oscillation in which a plurality of successive clockwise and counterclockwise movements are imparted to the headstock motor during each complete rotative movement thereof.

The foregoing embody the essential elements of the present invention for effecting, as described, a combined longitudinal or axial hydraulically effected oscillation of a multiple number of tool or abrading members, together with a relative bodily axial traversing or reciprocating movement of work piece and abrading members during which movement there is additionally imparted to the work piece the hereinabove described combined rotational and superimposed rotary oscillatory movements. In this manner a most efficient and effective relative scrubbing action or movement of abrading members and work piece surface is effected with a continuous change of relative direction of movement between an individual abrasive particle on the tool and the work such that there is no dragging or repetitious movement of the abrasive and its various cutting edges, each being momentarily operated and then shifted in a manner to clear same from any chips which might tend to cause a built-up edge, producing scratches or imperfections on the surface of the work.

The general hydraulic operation and control of the machine for effecting the foregoing results is diagrammatically illustrated in Figure 16 of the drawings. As there shown, there is provided a reservoir 152 from which hydraulic medium is supplied for actuation of the machine through pressure line 153. A suitable relief valve 154 maintains the pressure in the system at the desired value and permits of return of excess volume to reservoir through exhaust line 155. The conduit 153 is directly coupled to the grooved and ported bushing 156 containing the start and stop valve plunger 157 manually actuable as by movement of lever 158. With the parts in the stop position shown, the pressure is coupled by groove 159 with the return system 160 which is connected to one side of the left hand or rear platen control cylinder 52, shifting the rod 50 in a manner to cause retraction of the platen. It is further provided with a branch 160a having a pilot portion 160b effective to shift valve 161 in an upward position as shown, thereby coupling 160a with conduit 160c for discharge into the lower end of the right hand cylinder 52 effecting retraction of the front platen and abrading members carried thereby.

The several parts just described having reached their limit of movement under the influence of the coupled pressure oil, the pressure will tend to rise in conduit 160, as a result of which the sequence or delay valve 172 will be operated, permitting oil to flow into conduit 173. This reacts on valve 174 in chamber 175 moving same to the left.

The speed of valve plunger 174 moving to the left is controlled by the setting of the spring 202a in check valve 202. Three things happen in the following order when the valve plunger 174 moves to the left. First, conduit 201 is disconnected from line 204 which sets up the correct timing conditions for the platens when starting the cycle; second, conduit 176 is disconnected from conduit 122d which causes the headstock motor 91, and also the hydraulic motor 139, which drives the oscillator pumps, to stop; third, conduit 173 is connected to conduit 177 which enters chamber 179 and forces valve plunger 178 to the left. It should be noted at this time that when valve

plunger 174 was moved to the left the oil was discharged on the left end through check valve 202 to conduit 201a to conduit 201 through valve 200 to conduit 199 to conduit 198 to conduit 193 to conduit 128 to back pressure relief valve 129 to the reservoir through conduit 128'.

When valve 178 moves to the left the table is stopped because the connection between conduit 206 and conduit 190 is broken and conduit 190 is connected to conduit 191 to 192 to 193 to 128 to back pressure relief valve 129 to the reservoir through conduit 128'. The table stops because both ends of the table cylinder 34 are connected to exhaust pressure.

When valve plunger 178 moves to the left, oil is discharged from the left end through conduit 198 to conduit 193 to conduit 128 to back pressure relief valve 129 to the reservoir through conduit 128'.

From the above description it should be understood that by placing the start stop lever 158 in the position shown on Figure 16 that all machine functions are stopped in the following order: 1. The platens are returned, pulling the stones away from the work while the headstock is still running and the stones are still reciprocating slowly; 2. The headstock and stones stop moving after the stones have left the work; 3. The table stops.

The machine cycle is started by moving start stop lever 158 in a counterclockwise direction as viewed in Figure 16, initially to bring detent 194 in engagement with notch 195.

The machine functions start in the following order. First, the table starts to move; second, the headstock starts to rotate slowly, and the stones start to oscillate slowly; third, the platens move the stones into contact with the work; fourth, the speed of the headstock and stone oscillators is increased by moving the start stop lever 158 farther to the left which through link 158' moves start stop valve plunger 157 to the right and opens the throttle between conduit 122d and conduit 122.

When start stop valve is placed in the initial position, as described above, two things happen; first, conduit 153, which is connected to the pump, is connected to conduit 198; second, conduit 122d is connected to conduit 122 through the throttled portion of groove 196 in valve plunger 157. The connection of conduit 198 to a pressure source causes valve plunger 178 to move to the right, which causes two things to happen in the following order; first, conduit 206 is connected to line 190 which together with the passageway through the throttle valve 208 and conduit 188 make up the pressure connections which run the table. The table will, therefore, start first. The direction of table movement will depend on the position of the levers 213 and 211'. If the levers point to the left the table will move to the left; if the levers point to the right, the table will move to the right. Lever 213 is operated by dogs 214 which are fastened to the table as shown on Figure 1.

Lever 211' is hand operated and the operator can reverse the table at any time at any position of its stroke. When the levers 212 and 211' point to the left the oil supply into the table cylinder 34 is from conduit 190 through rate valve 208 to conduit 188 through reversing valve 187 to conduit 185. This will push the piston and rod 33 which carries the yoke 32 which is fastened to the table to the left. Oil will be exhausted through conduit 183 through the re-

versing valve 181 to conduit 180. When the pilot valve 211 trips by moving to the left, pressure oil is admitted from conduit 207 to passage 215 to the right hand side of reversing plunger 182 and the pilot plunger 211. Oil is exhausted from the left hand end through passage 210 to conduit 180. Conduit 207 is always connected to pump pressure. Second, conduit 198 is connected to conduit 199 which together with passageway through selector valve 200 and the conduits 201 and 201a forms the pressure connection to the left hand end of valve plunger 174 which causes it to move to the right.

It should be noted at this time that when valve plunger 178 is moved to the right that the oil discharged from the right hand side flows to the reservoir through conduit 177 through valve chamber 175 through conduit 173 through the check valve 172' through valve chamber 159 to conduit 193 through back pressure valve 129 to conduit 128'.

The pressure connection now formed at 201a causes the valve plunger to move to the right. The valve plunger moves to the right slowly because oil must pass through a restricting groove 202' which bypasses the check valve 202. When the valve plunger 174 moves to the right three things happen in the following order.

First, conduit 176 is connected to conduit 122d which together with the passageway through valve plunger 196 and conduits 122 and 122a form the pressure connections to the head-stock motor 91 and the hydraulic motor 139, which runs the oscillator pumps. The headstock and stone oscillation will start soon after the table starts. Second, conduit 201 is connected to conduit 204 through the valve passage 203 in valve plunger 174 which forms the pressure connection to the platen actuating cylinders.

It will be noted that conduit 204 at the rear of the machine is coupled to the outer or, as diagrammatically indicated, lower side of piston 51, tending to move the piston upward or in a direction to react on the platen controlling eccentrics, moving the abrading members carried thereby into engagement with the rear portion of the now rotating work. At the same time this pressure reacts through valve 161 to shift the piston 51 for the front platen and similarly move it and its supported abrading members into engagement with the front portion of the work, assuming that valve 161 remains in the position shown in the diagram.

It will, of course, be understood that if, for any reason, it is desired that the forward platen shall remain in retracted position with respect to the work, valve 161 may be manually operated as by control lever 205 to shift the valve from the position shown in Figure 16 to a lower position in which the pressure in 204 will react on the underside of the piston to maintain the parts retracted.

It should be understood that lever 205 must be moved to the right, and start stop lever 158 must be moved to the left simultaneously in order to obtain the above results.

The third thing that happens when valve plunger 174 moves to the right is that the connection between conduit 177 and 173 is broken, thereby setting up correct timing conditions for stopping the cycle. It should be noted at this time that when the valve plunger 174 moves to the right that the oil discharged on the right flows back to the reservoir through conduit 173 through the check valve 172', through the valve

passage 159 to conduit 193 through back pressure relief valve 129 to conduit 128'.

At this time the function of selector valves 208 and 200 should be explained.

In the position shown on Figure 16 the valve 208 acts as a throttle valve to control the speed of the table movement. If the valve plunger of selector valve 208 is pushed in, the connection between conduit 190 and 188 is broken and the connection between 188 and 189 is made. Therefore, the table will stop because both ends of the table cylinder 34 are connected to the reservoir, but all other machine functions will continue.

This condition is necessary for a plunge cut cycle, that is, when the work piece is shorter than the stone and the table traverse is unnecessary.

In the position shown on Figure 16 valve 200 merely acts as a passageway to connect conduit 199 to conduit 201 but if the plunger of valve 200 is moved to the right, not only is the connection between conduit 199 and conduit 201 broken but conduit 201 is connected to conduit 128 which is finally connected to the reservoir. Now, if the start-stop valve 157 is moved to the right or starting position the only thing that will run is the table. The other machine functions cannot start because the pressure connection to valve plunger 174 is blocked.

This valve is necessary for set-up conditions. The operator can line up the stones with that portion of the work piece to be finished without having the work rotate or the stones oscillating and in contact with the work.

At this time the function of hand lever 205, valve plunger 161 and 162 should be explained. On this machine it is possible to use fine abrasive stones on the rear set of stones for finishing and coarser abrasive stones on the front for roughing. At the will of the operator the front set of stones can be removed from the work by moving valve plunger 161 down by means of hand lever 205. This connects conduit 204 with 160c and 160d. Oil pressure in 160c causes the front platen operating cylinder to act and move the front platen which moves the front set of stones away from the work. Oil pressure in 160d moves valve plunger 162 down and this forms a connection between conduit 163 and 164 and between conduit 165 and 166. Conduits 163 and 164 are connected to two cylinders of the oscillator plunger pump, the pistons of which are moving in opposite directions and therefore the oil is merely pumped from one cylinder to the other and no oil is supplied to the stone oscillator cylinders. The same is true of conduits 165 and 166. When valve 161 is moved down the pressure in line 233 is dropped to exhaust pressure and therefore the spring 236, acting on plunger 222 of the cutting fluid shut-off valve shown in Figure 15, moves the plunger to the left and shuts off the cutting fluid supply. It should be understood now that the act of moving lever 205 to the right causes the front stones to be moved from the work, the stones to stop oscillating and the cutting fluid to cease to flow.

It should be understood that if the machine is now stopped by moving start-stop valve 157 to the left that the rear set of stones will be removed from the work and the front stones will remain in the retracted position. If the machine is now started again pressure in 160, 160a and 160b will move valve plunger 161 to the position shown, and then both platens carrying the cutting stones

will be advanced to the work at the proper time as explained above.

The function of cylinders 167—168—169—170 is explained as follows. If the work piece being finished is so short that all of the stones are not needed then the oscillation of those not needed can be stopped by unscrewing the control knob on as many plungers as there are stones which are not needed. From the diagram, Figure 16, it can be seen that each of the cylinders 167—168—169—170 is connected to one of the stone oscillator cylinders. The springs in the stone oscillator cylinders are very strong, while the springs in the impulse absorbing cylinders are very weak. Therefore, if the plunger in the impulse absorbing cylinder is free to move the stone will not oscillate.

In order that the flow of cutting fluid to the work may be automatically controlled and shut off when the stones are retracted from engagement with the work, use is made of the interconnected hydraulic control mechanism particularly illustrated in Figure 15. The cutting fluid from tank 83 is discharged by pump 84 and conduit 216, blotter filter 217 and conduit 218 to the relief valve mechanism having a first valve device 219 controlling discharge into the general supply line 220 branching to the individual shut-off valves 221, individual to the rear set of finishing heads, and 222, individual to the front set of finishing heads. The supply conduits 82 and 82a extend from these shut-off valves to the respective individual heads of the series.

The general relief valve has a second pressure determining valve 223 controlling flow into conduit 224 having branches as at 225 for effecting lubrication of the ways or other desired portions of the machine and an additional branch conduit 226 adapted to communicate through the series of check valves 227 Figure 16 with the series of conduits 228 individual to the various stone reciprocator motor groups, while the check valves 227 tend to retain the hydraulic actuating fluid in the various oscillator chambers of the stone oscillator motor; in the event of leakage they will yield, permitting the cutting fluid to replenish and keep the system filled. It is to be noted that outwardly opening relief valves 229 have been provided, permitting escape of fluid in the event of undue resistance to operation of the abradant reciprocating motors, and the conduit 226, therefore, also serves to replenish any fluid which may be lost in this manner so that the stone reciprocating system is at all times kept 100% filled and effective.

To control the opening and closing of the cutting fluid flow control valves 221 and 222, they have been provided with the hydraulically actuable plungers 230 and 231. Plunger 230 is coupled by conduit 232 with the conduit 204 which when under pressure is effective to cause inward or work-engaging movement of the rear set of work abrading members. Consequently, when actuating pressure exists in this line it will serve to move valve 221 to the right, as viewed in Figure 15, permitting suitable flow of cutting fluid. Conversely, when conduit 204 becomes a reservoir or low pressure conduit, spring 235 is effective to move the valve into closed position, shutting off the flow.

Similarly, plunger 231 is coupled by conduit 233 alternatively with either pressure conduit 204 or conduit 160, depending on the position of the individual control valve 161 for determining the position of platen motor 51. When the valve is in position to effect inward movement of the

front series of work abrading members, pressure will exist in conduit 233, opening valve 222 for flow of cutting fluid, while when the valve is shifted to cause independent retraction of the forward series of tools the flow is automatically shut off due to positioning of the valve by expansion of spring 236.

It will be understood that a suitable relief valve, as indicated at 237, may be employed to permit return of excess discharge of pump 84 to reservoir 83 when the valves 221 and 222 are closed.

From the foregoing it will be noted that in the operation of our improved finishing machine, through utilization of the various hydraulic and other control mechanisms shown and described, it is possible satisfactorily to initiate a relative traversing movement of the work and abrading members, to effect an initial slow starting up of the headstock motor with either a power rotative or combined rotation and superimposed movement of rotary oscillation, together with independent reciprocations of the various individual work engaging tools and to bring the moving tools automatically into engagement with the rotating work piece during the relative translation of tools and work piece in such manner that no initial scratching or marking will be produced on the work; and that after the parts have been so operatively related the additional shifting of the start control lever effects a speeding up of the relative work and tool movements for satisfactory performance of the surfacing operation.

At the same time the movement tending to cause interengagement of work and surfacing tools reacts on additional control mechanism to insure proper supply of cutting fluid medium as respects the particular tools being operatively related to the work. Conversely, upon stopping of the machine the cutting fluid flow is automatically discontinued, the tools retracted as respects the work piece and their reciprocating movement stopped and all relative movement between work and tools ceases.

Additionally, it is to be noted that in the case of a machine employing a multiplicity of tool holders the reciprocation of any individual tool can be checked at will, the tool individually retracted as respects the work, or disengaging pressure upon the work, individually varied as desired without effect on the action of its complementary interconnected opposed tool.

It is further to be noted that the structure in question assures a satisfactory cold cutting of the material being operated upon by providing a constantly changing direction of motion between the abrading elements and the work surface, thus preventing accumulation of chip material on any active facets of these elements, and thus maintaining a free cutting action. Also, that the particular configuration of path traced by an individual abrasive particle on the surface of the work as a result of the combined relative movements of tool and work may be of either the figure eight configuration shown in Figure 14 or of overlapping spiral whirls or other forms depending upon the modifications possible in the machine for changing the frequency ratio of the work oscillations and the longitudinal reciprocations of the abrading members, but that in any event the path is of a constantly changing character such that a particular side or facet on the individual abrasive particle is but momentarily effective when the cut is transferred to a

different angular relation about the periphery of the individual cutting point, tending to free the previously removed bit of metal from the point so that these infinitesimal chips will each be cleanly cut away or removed without dragging or tearing and be of such minute character as to be readily carried away by the provided cutting fluid flow.

As stated above, the stone oscillator plunger pump and the headstock oscillator plunger pump is shown only diagrammatically in the hydraulic diagram as shown on Figure 16.

By reference to Figure 17 it is evident that the headstock oscillator plunger pump 238 may be directly connected to the stone oscillator plunger pump 239 by means of coupling 138a and also to the hydraulic motor 139, which drives both pumps, by means of Oldham coupling 139a.

The stone oscillator pump 239 has eight cylinders, the construction of which are identical with those in the headstock oscillator plunger pump 238 as indicated by cylinders 135 and 140, pistons 136 and 141 and springs 142.

Each cylinder in the stone oscillator plunger pump is connected to one of the stone oscillator mechanisms by means of a flexible tube as shown at 81a, Figure 16.

The eight cylinders of the stone oscillating plunger pump 239 are arranged in two planes as indicated at 240 and 241, each plane containing four cylinders spaced 90° apart, while those in one plane are rotated 45° from those in the other plane such that when viewing the pump from the inside of the machine as shown in Figure 3 the cylinder heads and outlets are 45° apart.

The arrangement of the cylinders in the headstock oscillating pump 238 is similar to the arrangement in the stone oscillator pump 239 but for a different reason.

Owing to the large displacement of the headstock motor 91, the quantity of oil required is four times the quantity required to give stone oscillation. Therefore the eight cylinders of this pump are connected in parallel in two groups of four by means of interdrilling in the pump housing in such a manner that they act hydraulically as two opposed pistons and cylinders.

In order to provide a path for the abrasive grits relative to the work surface such as shown in Figure 14, the cams 137 on the headstock oscillator pump 238 are each provided with two lobes, while the corresponding cams on the stone oscillator pump 239 are each provided with four lobes, thus the frequency of oscillations of the headstock will be one-half that of the stone reciprocations. Moreover, the phase relation between headstock motion and stone is such as to produce the desired pattern, Figure 14.

If a circular path, instead of a figure eight, is desired for the abrasive, four lobes may also be used on each of the cams 137, and the phase relation between headstock motion and stone motion be made equal to one-fourth of the cycle angle.

If a varying path be desired for the abrasive, the number of lobes on the cam 137 may be either two or four, and the coupling 138a may be replaced by a gear box arranged to give a slightly different speed to the pump 239 relative to the pump 238.

It should be noted that the symmetrical design of the plunger pumps makes it possible to supply heavy springs 142 to hold the pistons against the rollers and the rollers against the camshaft without placing any unbalanced load on the cam shafts. As an extra precaution to in-

sure smooth running of the plunger pumps a flywheel 138b has been added to the rotating system.

A complete dynamic equilibrium of the machine may readily be obtained with respect to the reciprocating masses of the stone heads by making the phase relation of their motion such that each pair of diametrically opposed stones, and each pair of adjacent stones are 180° out of phase with each other. This provides a complete balance in the axial forces on the work and insures a steady and quietly operating machine.

What is claimed is:

1. A machine of the character described including a work support, means for supporting an abrading tool in opposition to a work piece carried by the support, a tool reciprocally mounted on said supporting means, means for effecting high speed reciprocation of said tool, means for effecting a progressive rotary advance of the work with respect to the tool and a simultaneous relative traverse of said parts, a hydraulic actuator, conduits coupling said actuator with said several means for effecting the operation thereof, said means for effecting the progressive rotary advance of the article including a hydraulic motor, a conduit for supplying actuating medium unidirectionally thereto at a predetermined rate, and additional means for effecting alternating pulsations in the motor supply fluid whereby a combined rotational advance and pulsating movements of rotary oscillation are imparted to the motor.

2. A machine of the character described including a work support, means for supporting an abrading tool in opposition to a work piece carried by the support, a tool reciprocally mounted on said supporting means, means for effecting high speed reciprocation of said tool, means for effecting a progressive rotary advance of the work with respect to the tool and a simultaneous relative traverse of said parts, a hydraulic actuator, conduits coupling said actuator with said several means for effecting the operation thereof, said means for effecting the progressive rotary advance of the article including a hydraulic motor, a conduit for supplying actuating medium unidirectionally thereto at a predetermined rate, additional means for effecting alternating pulsations in the motor supply fluid whereby a combined rotational advance and pulsating movements of rotary oscillation are imparted to the motor, and means for coupling the actuating medium to the motor inclusive or exclusive of said pulsator.

3. A machine of the character described including a work support, means for supporting an abrading tool in opposition to a work piece carried by the support, a tool reciprocally mounted on said supporting means, means for effecting high speed reciprocation of said tool, means for effecting a progressive rotary advance of the work with respect to the tool and a simultaneous relative traverse of said parts, a hydraulic actuator, conduits coupling said actuator with said several means for effecting the operation thereof, said means for effecting the progressive rotary advance of the article including a hydraulic motor, a conduit for supplying actuating medium unidirectionally thereto at a predetermined rate, additional means for effecting alternating pulsations in the motor supply fluid whereby a combined rotational advance and pulsating movements of rotary oscillation are imparted to the motor, means for coupling the actuating medium

to the motor inclusive or exclusive of said pul-
sator, an additional controller for determining
the operative connection or disconnection of the
hydraulic actuator with the hydraulic motor, and
means actuable by said additional controller for
determining the effective positioning of the tool
holding means with respect to the motor actuated
work piece.

4. A finishing machine of the character de-
scribed, including a bed, headstock and tailstock
members intermediately mounted on the bed for
support of a work piece therebetween, tool sup-
porting carriages mounted on the bed on op-
posite sides of the potential work position, means
for determining the joint or individual move-
ment of the tool supports toward and from the
work position, means for effecting a back and
forth translation of the work supports on the
bed, individual tool holders carried by the tool
supports, means for individually effecting vi-
bratory reciprocations of the individual tool sup-
ports, a hydraulic headstock motor, means for
supplying actuating fluid to the headstock motor
at a predetermined rate for effecting rotation
of the headstock and thus of a supported work
piece with respect to the vibrating tool supports,
and additional means for producing alternating
vibratory pulsations in the fluid supply to the
headstock motor whereby a rotary oscillatory
movement is superimposed on the primary rotary
movement of the headstock, substantially as and
for the purpose described.

5. A finishing machine of the character de-
scribed, including a bed, headstock and tailstock
members intermediately mounted on the bed for
support of a work piece therebetween, tool sup-
porting carriages mounted on the bed on op-
posite sides of the potential work position, means
for determining the joint or individual move-
ment of the tool supports toward and from the
work position, means for effecting a back and
forth translation of the work supports on the
bed, individual tool holders carried by the tool
supports, means for individually effecting vi-
bratory reciprocations of the individual tool sup-
ports, a hydraulic headstock motor, means for
supplying actuating fluid to the headstock motor
at a predetermined rate for effecting rotation
of the headstock and thus of a supported work
piece with respect to the vibrating tool supports, ad-
ditional means for producing alternating vibratory
pulsations in the fluid supply to the headstock
motor whereby a rotary oscillatory movement is
superimposed on the primary rotary movement
of the headstock, said means for effecting vibra-
tion of the tool holders comprising hydraulic mo-
tors individual to the respective tool holders, a
hydraulic circuit including the motors, and
means for creating alternating pulsations in said
circuit for actuation of the motors, substantially
as and for the purpose described.

6. A finishing machine of the character de-
scribed, including a bed, headstock and tailstock
members intermediately mounted on the bed for
support of a work piece therebetween, tool sup-
porting carriages mounted on the bed on opposite
sides of the potential work position, means for
determining the joint or individual movement of
the tool supports toward and from the work po-
sition, means for effecting a back and forth
translation of the work supports on the bed, in-
dividual tool holders carried by the tool supports,
means for individually effecting vibratory recip-
rocations of the individual tool supports, a hy-
draulic headstock motor, means for supplying

actuating fluid to the headstock motor at a pre-
determined rate for effecting rotation of the
headstock and thus of a supported work piece
with respect to the vibrating tool supports, ad-
ditional means for producing alternating vibratory
pulsations in the fluid supply to the headstock
motor whereby a rotary oscillatory movement is
superimposed on the primary rotary movement
of the headstock, said means for effecting vibra-
tion of the tool holders comprising hydraulic
motors individual to the respective tool holders,
a hydraulic circuit including the motors, means
for creating alternating pulsations in said circuit
for actuation of the motors, and a constantly
driven member having individual elements for
producing the tool and the headstock motor
pulsations, substantially as and for the purpose
described.

7. A finishing machine of the character de-
scribed, including a bed, headstock and tailstock
members intermediately mounted on the bed for
support of a work piece therebetween, tool sup-
porting carriages mounted on the bed on op-
posite sides of the potential work position, means
for determining the joint or individual movement
of the tool supports toward and from the work
position, means for effecting a back and forth
translation of the work supports on the bed, in-
dividual tool holders carried by the tool sup-
ports, means for individually effecting vibratory
reciprocations of the individual tool supports, a
hydraulic headstock motor, means for supplying
actuating fluid to the headstock motor at a pre-
determined rate for effecting rotation of the
headstock and thus of a supported work piece
with respect to the vibrating tool supports, ad-
ditional means for producing alternating vibratory
pulsations in the fluid supply to the headstock
motor whereby a rotary oscillatory movement
is superimposed on the primary rotary movement
of the headstock, said means for effecting vibra-
tion of the tool holders comprising hydraulic mo-
tors individual to the respective tool holders, a
hydraulic circuit including the motors, means
for creating alternating pulsations in said circuit
for actuation of the motors, a constantly driven
member having individual elements for produc-
ing the tool and the headstock motor pulsations,
and a single control member for simultaneously
determining the actuation of the several hy-
draulically operated members.

8. A finishing machine of the character de-
scribed, including a bed, headstock and tailstock
members intermediately mounted on the bed for
support of a work piece therebetween, tool sup-
porting carriages mounted on the bed on op-
posite sides of the potential work position, means
for determining the joint or individual move-
ment of the tool supports toward and from the
work position, means for effecting a back and
forth translation of the work supports on the
bed, individual tool holders carried by the tool
supports, means for individually effecting vi-
bratory reciprocations of the individual tool sup-
ports, a hydraulic headstock motor, means for
supplying actuating fluid to the headstock motor
at a predetermined rate for effecting rotation
of the headstock and thus of a supported work
piece with respect to the vibrating tool supports, ad-
ditional means for producing alternating vibratory
pulsations in the fluid supply to the headstock
motor whereby a rotary oscillatory movement is
superimposed on the primary rotary movement
of the headstock, said means for effecting vibra-
tion of the tool holders comprising hydraulic

motors individual to the respective tool holders, a hydraulic circuit including the motors, means for creating alternating pulsations in said circuit for actuation of the motors, a constantly driven member having individual elements for producing the tool and the headstock motor pulsations, a single control member for simultaneously determining the actuation of the several hydraulically operated members, and a selector device for determination of the reaction effect of the headstock motor pulsator on said motor.

9. A finishing machine of the character described, including a bed, headstock and tailstock members intermediately mounted on the bed for support of a work piece therebetween, tool supporting carriages mounted on the bed on opposite sides of the potential work position, means for determining the joint or individual movement of the tool supports toward and from the work position, means for effecting a back and forth translation of the work supports on the bed, individual tool holders carried by the tool supports, means for individually effecting vibratory reciprocations of the individual tool supports, a hydraulic headstock motor, means for supplying actuating fluid to the headstock motor at a predetermined rate for effecting rotation of the headstock and thus of a supported work piece with respect to the vibrating tool supports, additional means for producing alternating vibratory pulsations in the fluid supply to the headstock motor whereby a rotary oscillatory movement is superimposed on the primary rotary movement of the headstock, said means for effecting vibration of the tool holders comprising hydraulic motors individual to the respective tool holders, a hydraulic circuit including the motors, means for creating alternating pulsations in said circuit for actuation of the motors, a constantly driven member having individual elements for producing the tool and the headstock motor pulsations, a single control member for simultaneously determining the actuation of the several hydraulically operated members, and selector devices for determining the operative effect of the pulsator devices as respects the individual tool holders.

10. A finishing machine of the character described, including a bed, headstock and tailstock members intermediately mounted on the bed for support of a work piece therebetween, tool supporting carriages mounted on the bed on opposite sides of the potential work position, means for determining the joint or individual movement of the tool supports toward and from the work position, means for effecting a back and forth translation of the work supports on the bed, individual tool holders carried by the tool supports, means for individually effecting vibratory reciprocations of the individual tool supports, a hydraulic headstock motor, means for supplying actuating fluid to the headstock motor at a predetermined rate for effecting rotation of the headstock and thus of a supported work piece with respect to the vibrating tool supports, additional means for producing alternating vibratory pulsations in the fluid supply to the headstock motor whereby a rotary oscillatory movement is superimposed on the primary rotary movement of the headstock, said means for effecting vibration of the tool holders comprising hydraulic motors individual to the respective tool holders, a hydraulic circuit including the motors, means for creating alternating pulsations in said circuit for actuation of the motors, a constantly

driven member having individual elements for producing the tool and the headstock motor pulsations, a single control member for simultaneously determining the actuation of the several hydraulically operated members, and individual selector devices for determining the reaction effect of the pulsator means on the headstock motor and on the tool holders.

11. A finishing machine of the character described, including a work support, a tool carrying platen, means for moving the platen in the direction of the work support for engagement with a work piece carried thereby, a tool support mounted on the platen, a reciprocable tool carried by the support, means for effecting reciprocation of the tool, means for effecting a relative translation of the support and platen to produce a traversing movement between the work and tool, a first mechanism for imparting a rotary movement to the work support, a second mechanism for concomitantly effecting a pulsating oscillation of rotary type of the work support during its rotation, a hydraulic control circuit for the several work and tool shifting members including multiple successively shiftable valve elements, and a control for said hydraulic circuit actuable to effect relative traverse of the tool platen and work support and relative approach movement and simultaneously effect initial slow and subsequent accelerated movements of the work and tool driving elements.

12. A finishing machine of the character described, including a work support, a tool carrying platen, means for moving the platen in the direction of the work support for engagement with a work piece carried thereby, a tool support mounted on the platen, a reciprocable tool carried by the support, means for effecting reciprocation of the tool, means for effecting a relative translation of the support and platen to produce a traversing movement between the work and tool, a first mechanism for imparting a rotary movement to the work support, a second mechanism for concomitantly effecting a pulsating oscillation of rotary type of the work support during its rotation, a hydraulic control circuit for the several work and tool shifting members including multiple successively shiftable valve elements, a control for said hydraulic circuit actuable to effect relative traverse of the tool platen and work support and relative approach movement and simultaneously effect initial slow and subsequent accelerated movements of the work and tool driving elements, and additional control means for variably determining the ratio of rotary and pulsating movements of the rotary work support.

13. A finishing machine of the character described, including a work support, a tool carrying platen, means for moving the platen in the direction of the work support for engagement with a work piece carried thereby, a tool support mounted on the platen, a reciprocable tool carried by the support, means for effecting reciprocation of the tool, means for effecting a relative translation of the support and platen to produce a traversing movement between the work and tool, a first mechanism for imparting a rotary movement to the tool support, a second mechanism for concomitantly effecting a pulsating oscillation of rotary type of the work support during its rotation, a hydraulic control circuit for the several work and tool shifting members including multiple successively shiftable valve elements, a control for said hydraulic circuit

actuable to effect relative traverse of the tool platen and work support and relative approach movement and simultaneously effect initial slow and subsequent accelerated movements of the work and tool driving elements, and selector means for determining the effective reaction of the hydraulic circuit on the work rotating and tool reciprocating elements.

14. A machine of the character described including a bed, a work support mounted thereon, a hydraulic motor for effecting rotation of the work support, tool supports carried by the bed having tool portions for operative engagement with a work piece held by the rotary support, and means for effecting actuation of the parts including a first hydraulic circuit for effecting rotation of the hydraulic motor, a second hydraulic circuit including a motor and a plurality of pulsators driven thereby, an operative connection between one of the pulsators and the hydraulic motor for effecting alternating pulsations of rotary oscillation of the motor supplementing the hydraulic rotation thereof effectable by the first-mentioned circuit.

15. A machine of the character described including a bed, a work support mounted thereon, a hydraulic motor for effecting rotation of the work support, tool supports carried by the bed having tool portions for operative engagement with a work piece held by the rotary support, means for effecting actuation of the parts including a first hydraulic circuit for effecting rotation of the hydraulic motor, a second hydraulic circuit including a motor and a plurality of pulsators driven thereby, an operative connection between one of the pulsators and the hydraulic motor for effecting alternating pulsations of rotary oscillation of the motor supplementing the hydraulic rotation thereof effectable by the first-mentioned circuit, reciprocable hydraulic motors individual to the respective tools, and hydraulic connections between the other pulsators and said motors for determining the individual reciprocations of the tools.

16. A machine of the character described including a bed, a work support mounted thereon, a hydraulic motor for effecting rotation of the work support, tool supports carried by the bed having tool portions for operative engagement with a work piece held by the rotary support, means for effecting actuation of the parts including a first hydraulic circuit for effecting rotation of the hydraulic motor, a second hydraulic circuit including a motor and a plurality of pulsators driven thereby, an operative connection between one of the pulsators and the hydraulic motor for effecting alternating pulsations of rotary oscillation of the motor supplementing the hydraulic rotation thereof effectable by the first-mentioned circuit, reciprocable hydraulic motors individual to the respective tools, hydraulic connections between the other pulsators and said motors for determining the individual reciprocations of the tools, and controllable means coupled with said connections for absorbing the pulsations to prevent reciprocation of the tools.

17. In a machine of the character described, the combination with a bed, a work support mounted thereon, of tool carrying platens disposed at opposite sides of the support, tools carried thereby for engagement with a work piece, individual hydraulic motors for controlling the position of the tool platens with respect to the work support, and control means for effecting joint or individual actuation of the motors for

corresponding movements of the platens with respect to the work support.

18. In a machine of the character described, the combination with a bed, a work support mounted thereon, of tool carrying platens disposed at opposite sides of the support, tools carried thereby for engagement with a work piece, individual hydraulic motors for controlling the position of the tool platens with respect to the work support, control means for effecting joint or individual actuation of the motors for corresponding movements of the platens with respect to the work support, means for supplying cutting fluid to the tools, flow control valves individual to the respective platens, and hydraulic connections intervening the platen shifting motors and said valves for effecting opening and closing of the valves in prescribed relation to the positioning of the platens.

19. In a machine of the character described, including a rotatably mounted work support, a tool support, means for effecting relative translation of said supports, and means for imparting rotational movement to the work support, of hydraulic actuating means for the parts, and means for controlling the power reaction of the hydraulic actuating means on the parts including a starting valve, serially arranged pilot and selector valves for determining the coupling of the hydraulic actuator to effect movement of the various parts, or selectively effecting the relative translation only, an additional actuation determining valve individually controlling the relative reciprocation irrespective of the position of the serially arranged valves, and an additional valve serially disposed with respect to said last mentioned valve for determining the direction of relative reciprocation of the parts.

20. A tool holding mechanism for a machine of the character described, including a yieldably mounted head having transverse guides formed thereon, a stone holder slidably mounted in said guides having an actuating projection to one side thereof, a piston member engaged on said projection, a chamber formed in the head and receiving said piston, opposed springs contained within the chamber oppositely reacting on the piston, and means for effecting hydraulic power pulsations in one end of the chamber for effecting successive compressions of the opposed piston engaging spring, whereby ultimate movement of the piston in both directions will be absorbed by the respective springs, and a smooth high speed reciprocation imparted to the tool holder, substantially as and for the purpose described.

21. A machine of the character described, including work and tool supporting means, means to effect a relative traverse of said parts, means to effect independent reciprocation of the tool, means to effect rotation of the work, and a single control device having a first position effective to initiate said relative traverse reciprocation and work rotation movements and to bring the tool and work into operative engagement one with the other, and a second position for effecting a speeding up of certain of said movements subsequent to said relative engagement of the parts.

22. A machine of the character described, including work and tool supporting means, means to effect a relative traverse of said parts, means to effect independent reciprocation of the tool, means to effect rotation of the work, and a single control device having a first position effective to initiate said relative traverse reciprocation and work rotation movements and to bring the

tool and work into operative engagement one with the other, and a second position for effecting a speeding up of certain of said movements subsequent to said relative engagement of the parts, said control having a third position effective to stop all of said relative movements.

23. A machine of the character described, including work and tool supporting means, means to effect a relative traverse of said parts, means to effect independent reciprocation of the tool, means to effect rotation of the work, a single control device having a first position effective to initiate said relative traverse reciprocation and work rotation movements and to bring the tool and work into operative engagement one with the other, and a second position for effecting a speeding up of certain of said movements subsequent to said relative engagement of the parts, said control having a third position effective to stop all of said relative movements, and a separate selector device independently operable for controlling the rotation of the work.

24. A machine of the character described, including work and tool supporting means, means to effect a relative traverse of said parts, means to effect independent reciprocation of the tool, means to effect rotation of the work, a single control device having a first position effective to initiate said relative traverse reciprocation and work rotation movements and to bring the tool and work into operative engagement one with the other, and a second position for effecting a speeding up of certain of said movements subsequent to said relative engagement of the parts, said control having a third position effective to stop all of said relative movements, a separate selector device independently operable for controlling the rotation of the work, and an additional independently operable device for determining the rate of relative reciprocation of the work and tool supports.

25. A machine of the character described, including multiple reciprocable tool holders, hydraulic motors individual to the respective tool holders for effecting reciprocation thereof, pulsators individual to said motors, a single actuator for operating said pulsators, and means for varying the stroke of the tool motors for a given impulse of their pulsators.

26. A machine of the character described, including multiple reciprocable tool holders, hydraulic motors individual to the respective tool holders for effecting reciprocation thereof, pulsators individual to said motors, a single actuator for operating said pulsators, means for varying the speed of said actuator to vary the rate of reciprocation of the tool motors, and means for individually varying the effective reciprocating strokes of the tool motors for a corresponding operation of their actuators.

27. A machine of the character described, the combination with means for supporting a tool and a work piece one in opposition to the other, of hydraulically operable means for effecting rotation of the work piece, hydraulically operable means for effecting reciprocation of the tool with respect to the work piece, a first means for effecting pulsations in the rotary movement of the work piece, a second means for effecting pulsations of reciprocation of the tool and a common driver for both of said pulsation effecting means.

28. A machine of the character described, the combination with means for supporting a tool and a work piece one in opposition to the other, of hydraulically operable means for effecting ro-

tation of the work piece, hydraulically operable means for effecting reciprocation of the tool with respect to the work piece, a first means for effecting pulsations in the rotary movement of the work piece, a second means for effecting pulsations of reciprocation of the tool, a common driver for both of said pulsation effecting means, and means for varying the rate of actuation of said common driver.

29. In a mechanism of the character described, the combination with a tool support, of a tool holder mounted thereon for reciprocation with respect thereto, a piston carried by the support and coupled with the tool holder, opposed resilient means reacting on the piston to effect substantial centralization thereof, a hydraulic conduit coupled for reaction on the piston, and means for effecting actuating pulsations of hydraulic fluid in the conduit.

30. A machine of the character described, including a bed having multiple sets of parallel ways formed thereon, a work support translatably mounted on certain of said ways, and tool supports translatably mounted on the ways on opposite sides of the work support, means for effecting translation of the work support with respect to the tool supports, and means for effecting joint or individual movement of the tool supports in directions toward and away from the work support.

31. A machine of the character described, including a bed, a platen mounted on the bed, means guiding the platen for sliding movement with respect to the bed, and means for effecting said sliding movement including a pair of rotary spindles journaled in the bed, eccentrics carried by the spindles and engaging the platen, hydraulically actuable means for effecting rotation of the spindles whereby the eccentrics will move the platen with respect to the bed, and means for effecting rotation of the spindles and thus of their eccentrics for moving the platen in one direction or another with respect to the bed, said means including pinion portions individual to the respective spindles, a reciprocable hydraulic motor, and rack members meshing with the pinions and coupled with the motor, substantially as and for the purpose described.

32. In a machine of the character described, including work supporting means, a platen, means for urging the platen in a direction toward the work supporting means, a plurality of tool supporting devices mounted on the platen for adjustment in a first direction toward and away from each other and in an angularly related direction toward and away from the work support, means individual to the respective tool supports for independently urging them in a direction toward the work support, tool holders reciprocably mounted on the individual tool supports, and means for effecting reciprocations of the tool holders of the several supports in prescribed phased relation.

33. A machine of the character described, including a pair of hydraulically reciprocable tool holders, means for effecting oppositely phased hydraulic pulsations for effecting reciprocation of the tool holders including individual hydraulic circuits for the respective tool holders, and means for interconnecting the circuits of the tool holders whereby said pulsating effects are self-neutralizing.

34. A finishing machine of the character described having a bed, a work supporting table reciprocably mounted on the bed, headstock and

tailstock units mounted on the table, a fluid oscillatory rotatable motor mounted in the headstock for imparting oscillatory rotational movement to a work piece supported between said stocks, finish tooling means mounted on the bed for engagement with the work, a fluid operable motor for reciprocating said table, a table control circuit including a source of fluid pressure, a start-stop valve for initial coupling of said pressure to said circuit, a reversing valve mechanism for the table motor and having potential pressure ports, a rate and selector valve, valve means shiftable in response to activation of said circuit for coupling said source of pressure to said potential pressure ports by way of said rate valve, and other valve means subsequently automatically operable for effecting actuation of the remaining motor means, said rate valve being shiftable from a rate controlling position to a selecting position for rendering the table motor inoperative while maintaining actuation of the remaining motor means.

35. A finishing machine having a bed, a work supporting table reciprocably mounted on the bed, means for rotatably supporting a work piece on the table including a work control motor for imparting oscillatory rotational movement to the work piece, a plurality of tooling devices shiftable into engagement with the work, means to control operation of said devices including a start and stop control lever mounted on the bed, means responsive to initial movement of said lever to

initiate operation of said work control motor and engagement of the tools with the work, other means responsive to movement of said lever for effecting oscillation of said tools at a prescribed rate, and means responsive to an additional movement of said lever to increase the rate of operation of said work control motor and said tool oscillating means.

36. In a finishing machine having a bed, a plurality of tooling devices carried by the bed and a work supporting table mounted on the bed for bodily movement relative to said tooling devices, the combination of control means for said table including table control valving, a first control circuit and a second control circuit, a source of pressure directly connected to one of said circuits, a start and stop control lever mounted on the bed, valve means responsive to movement of the lever for connecting said source of pressure to the second circuit, said valving having ports directly connected to the first circuit for controlling the direction of table movement and other ports potentially connectible to the second circuit, a valve energizable upon fluid connection to the second circuit for completing said potential connection, and valve means in said potential connection having a first motion for throttling the flow to said table motor and a second motion for stopping said table.

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