May 26, 1942. H. A. SILVEN 2,284,073

GRINDING MACHINE

Filed March 27, 1940 14 Sheets-Sheet 1

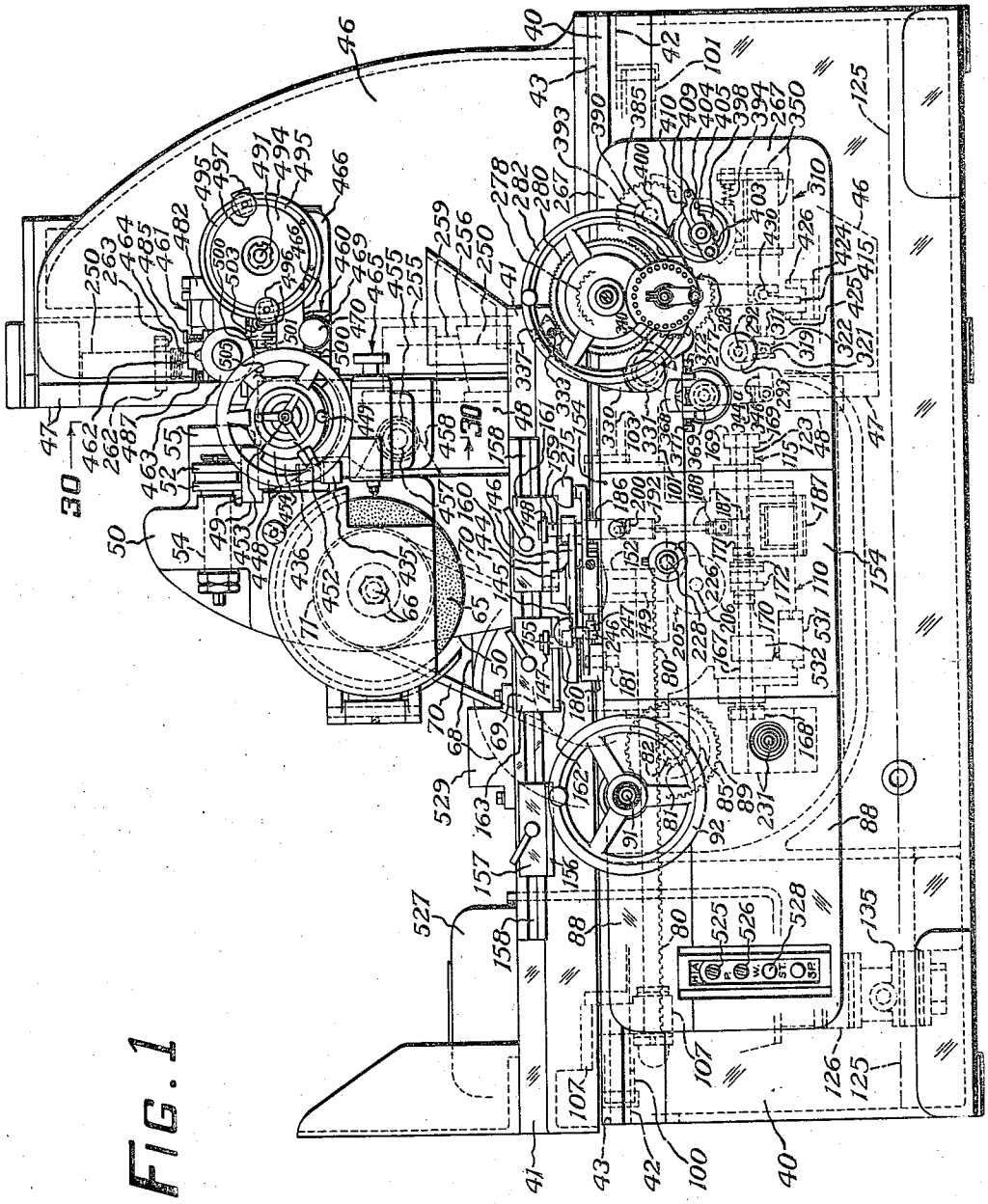

FIG. 1

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GRINDING MACHINE

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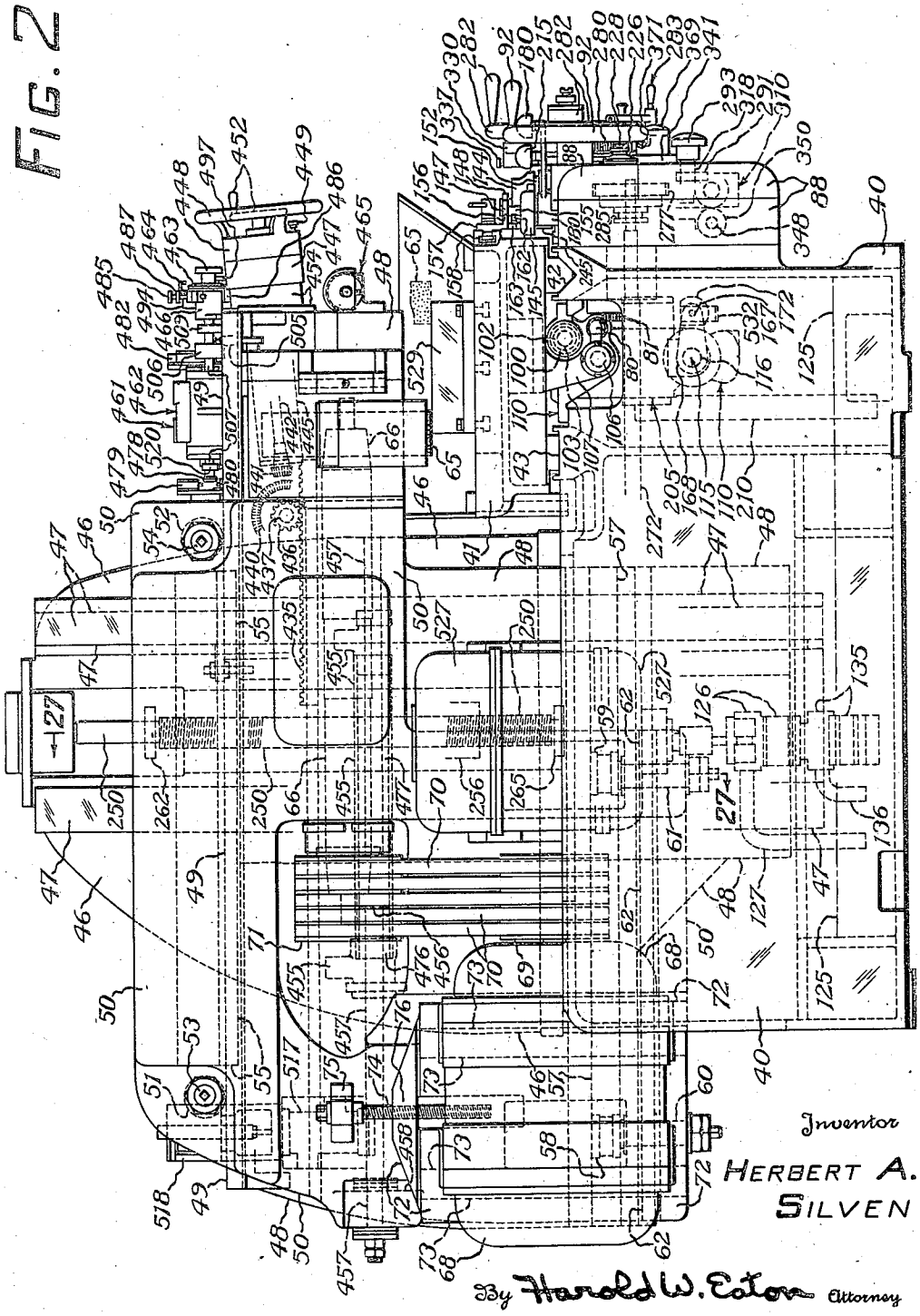
FIG. 2



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May 26, 1942. H. A. SILVEN 2,284,073

GRINDING MACHINE

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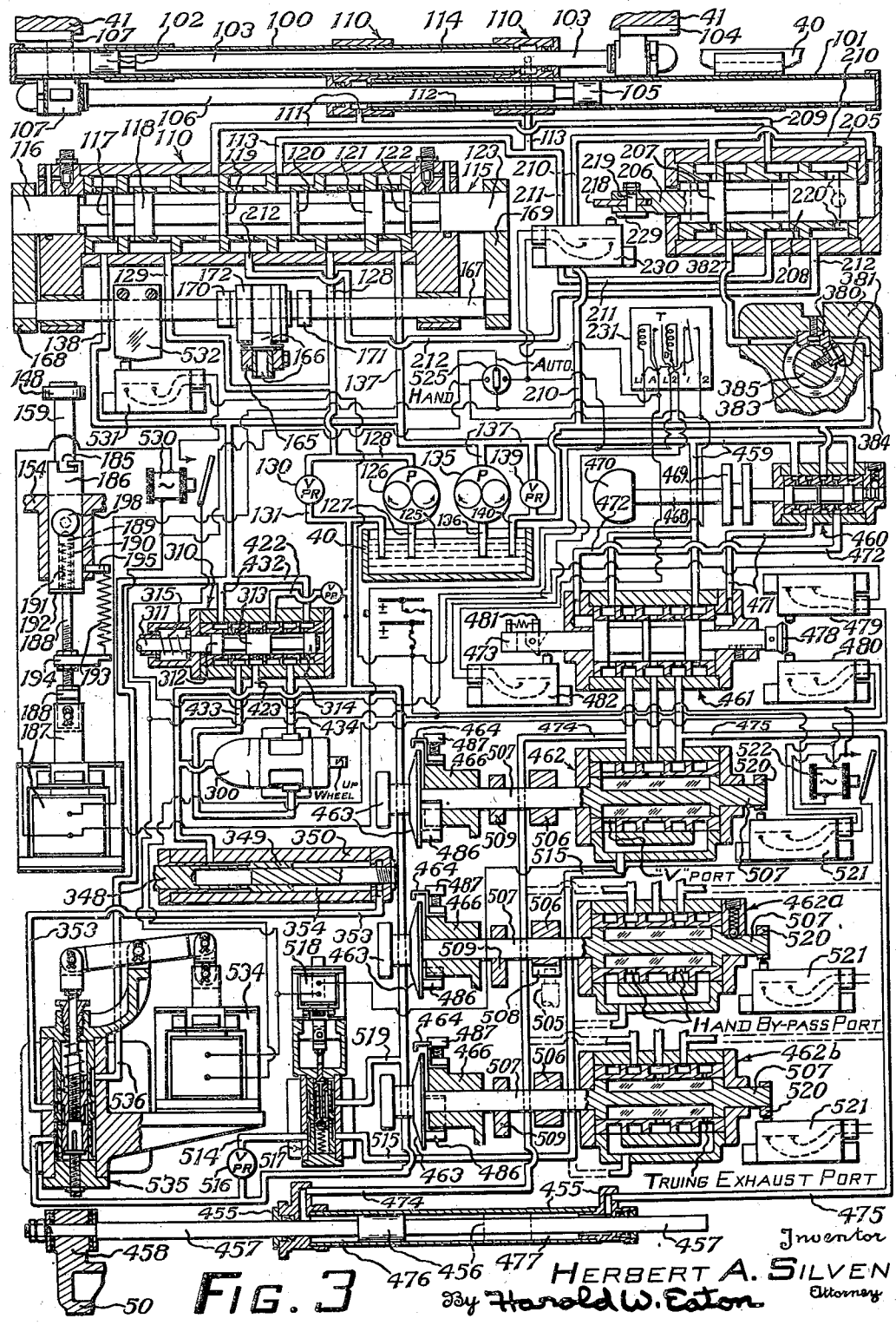

FIG. 3

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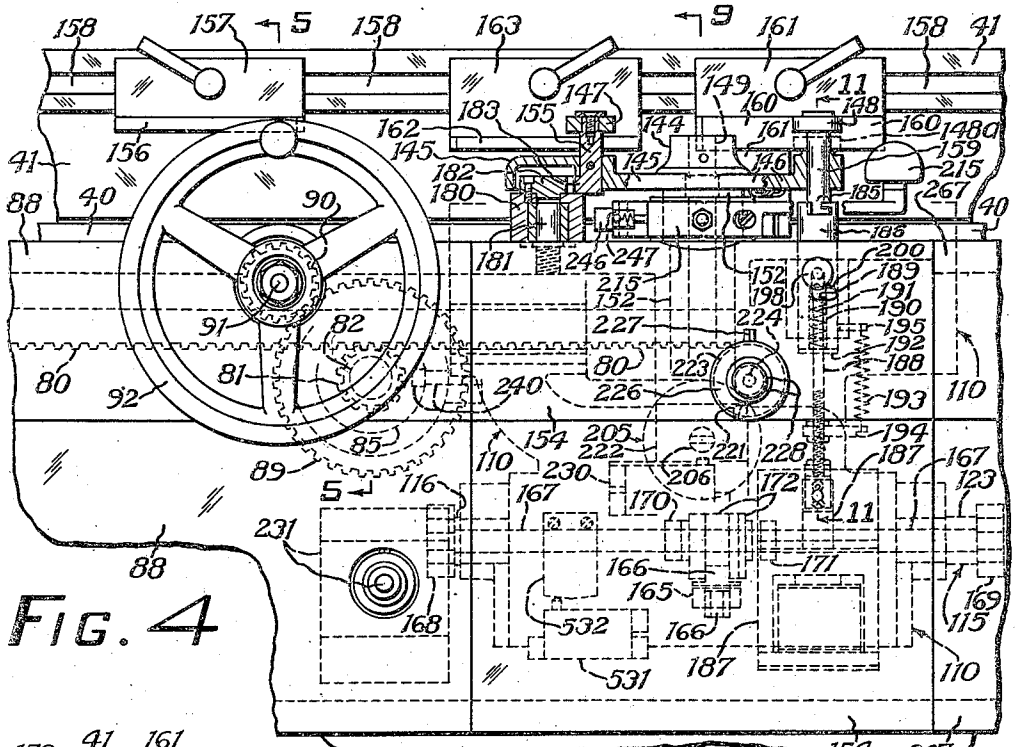

FIG. 4

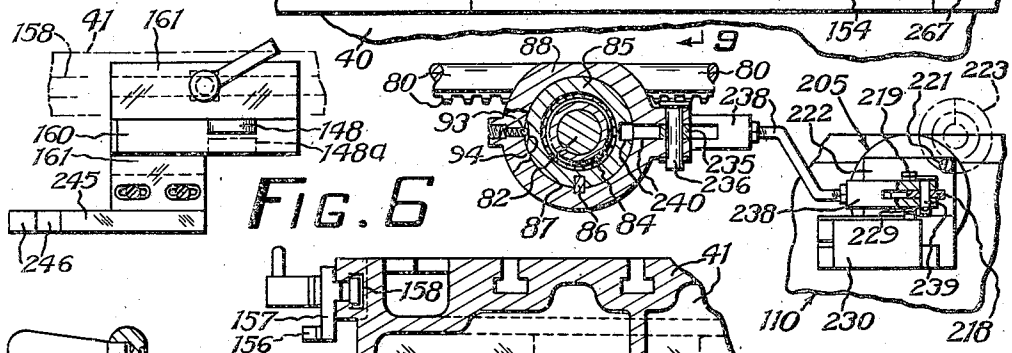

FIG. 6

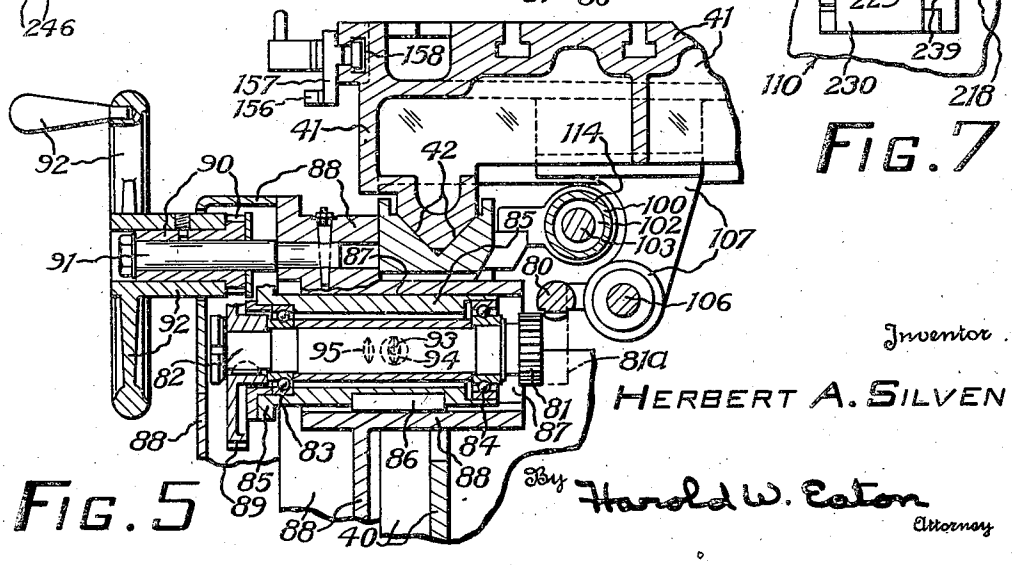

FIG. 7

FIG. 5

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FIG. 10

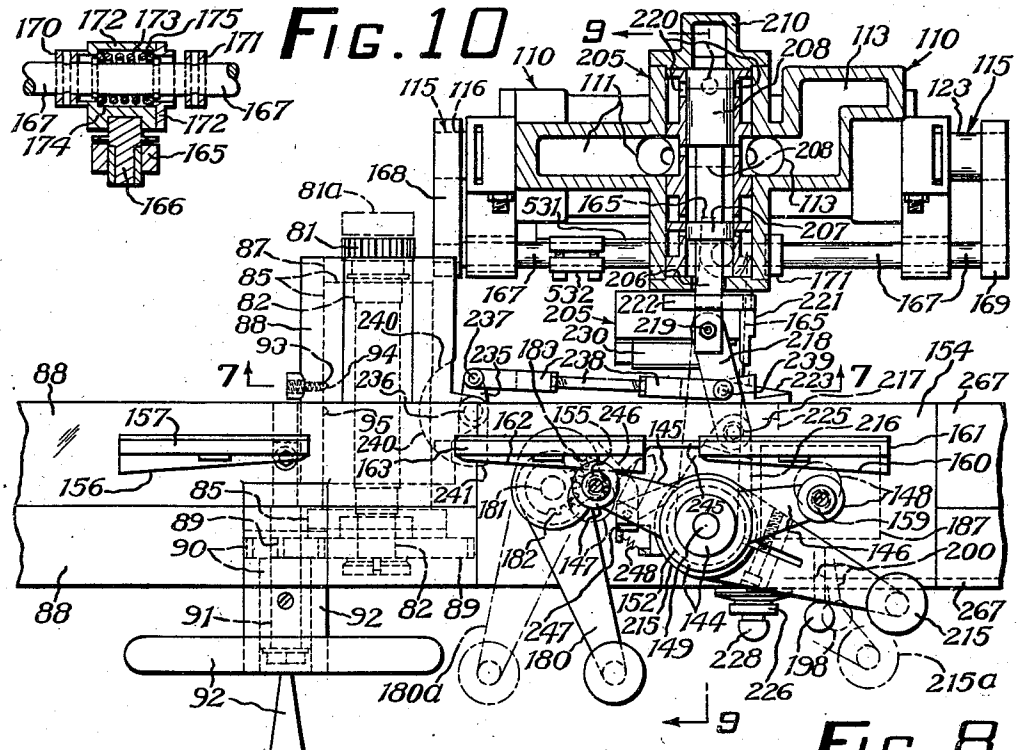

FIG. 8

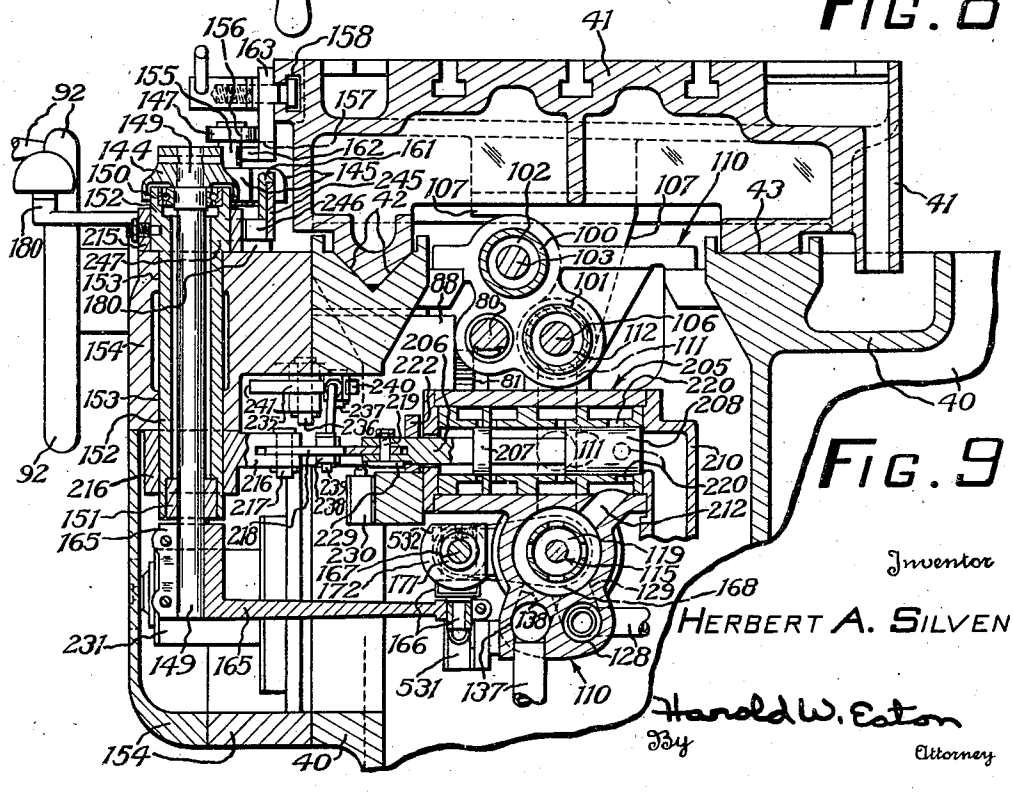

FIG. 9

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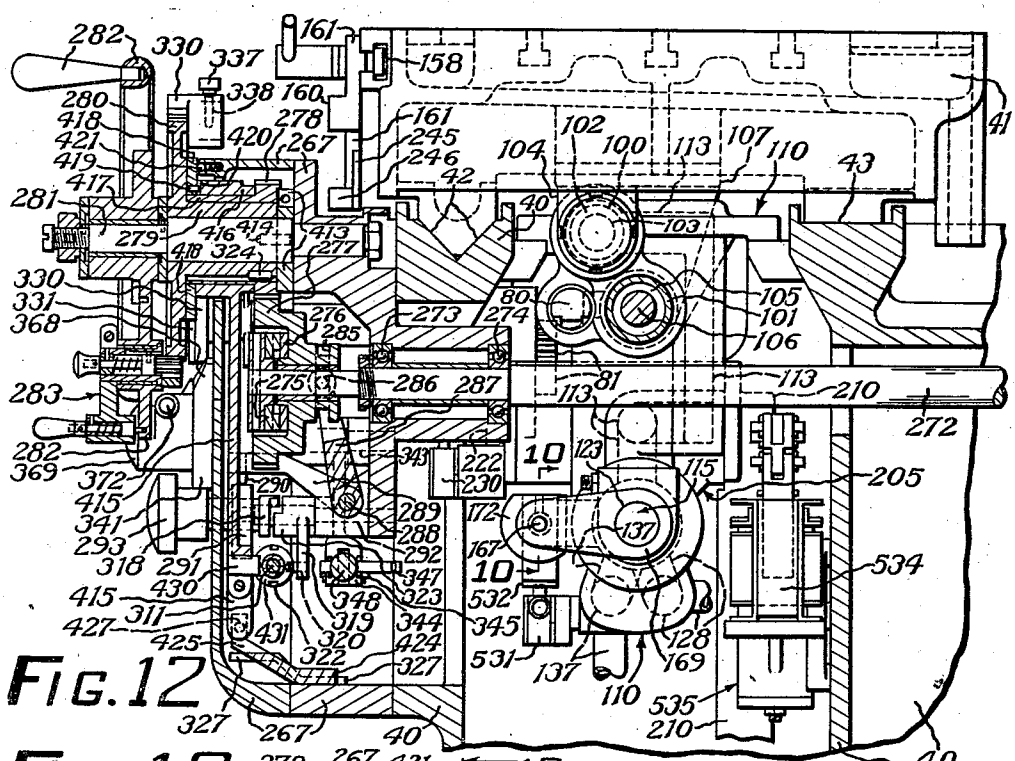

FIG. 12

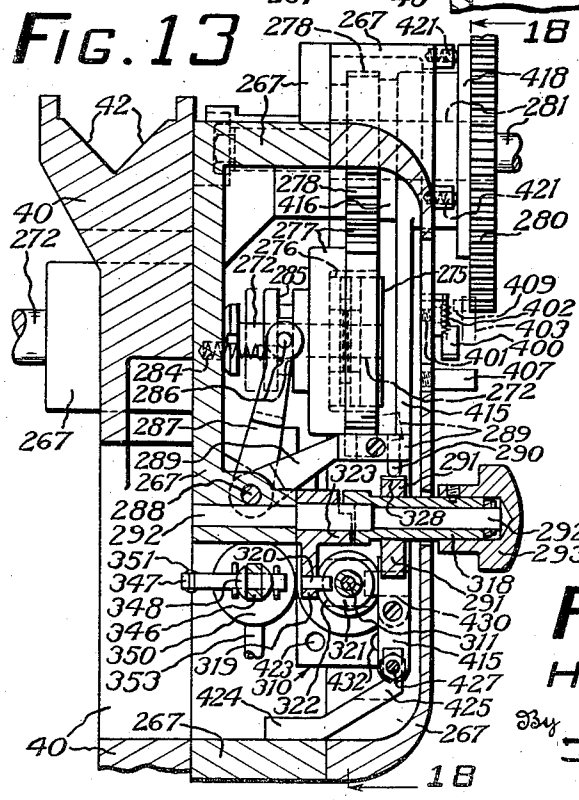

FIG. 13

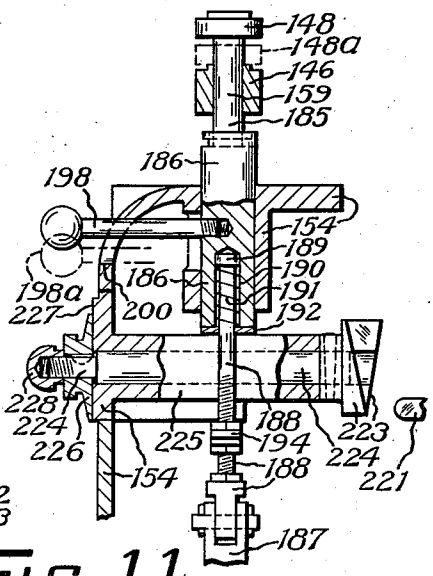

FIG. 11

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GRINDING MACHINE

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FIG. 14

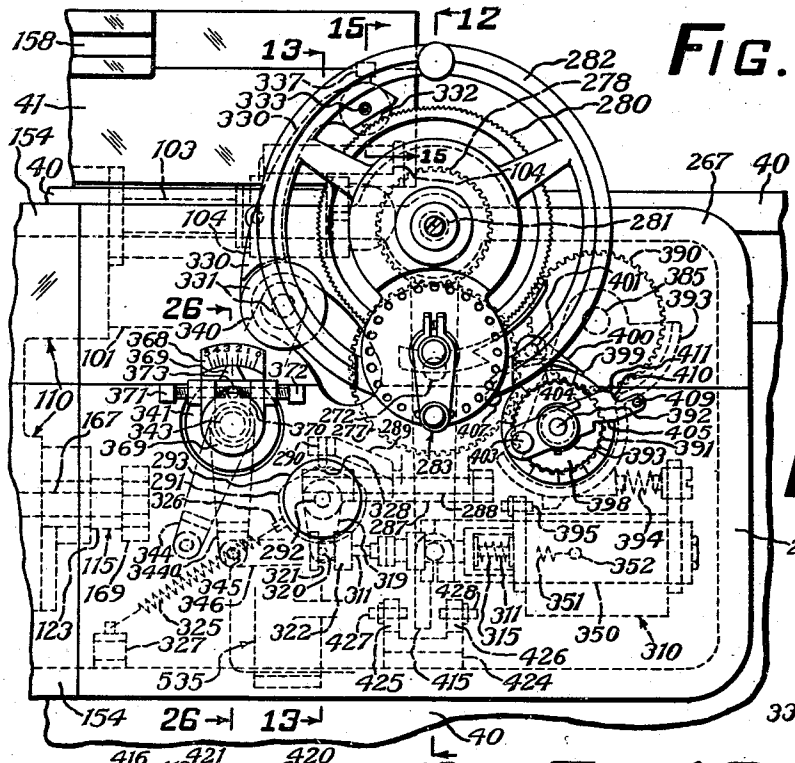


FIG. 17

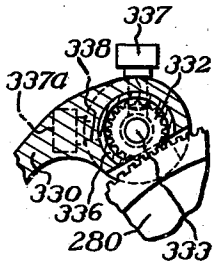


FIG. 18

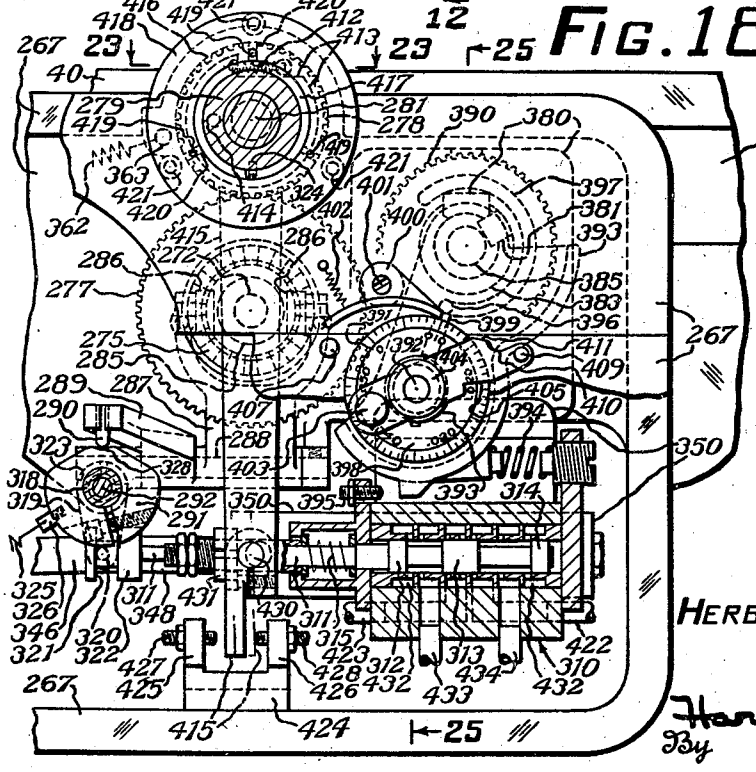


FIG. 16

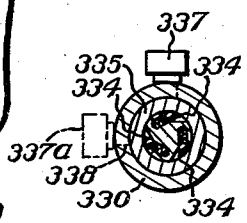
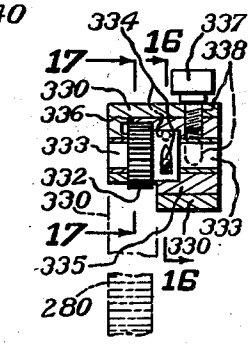


FIG. 15



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GRINDING MACHINE

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FIG. 19

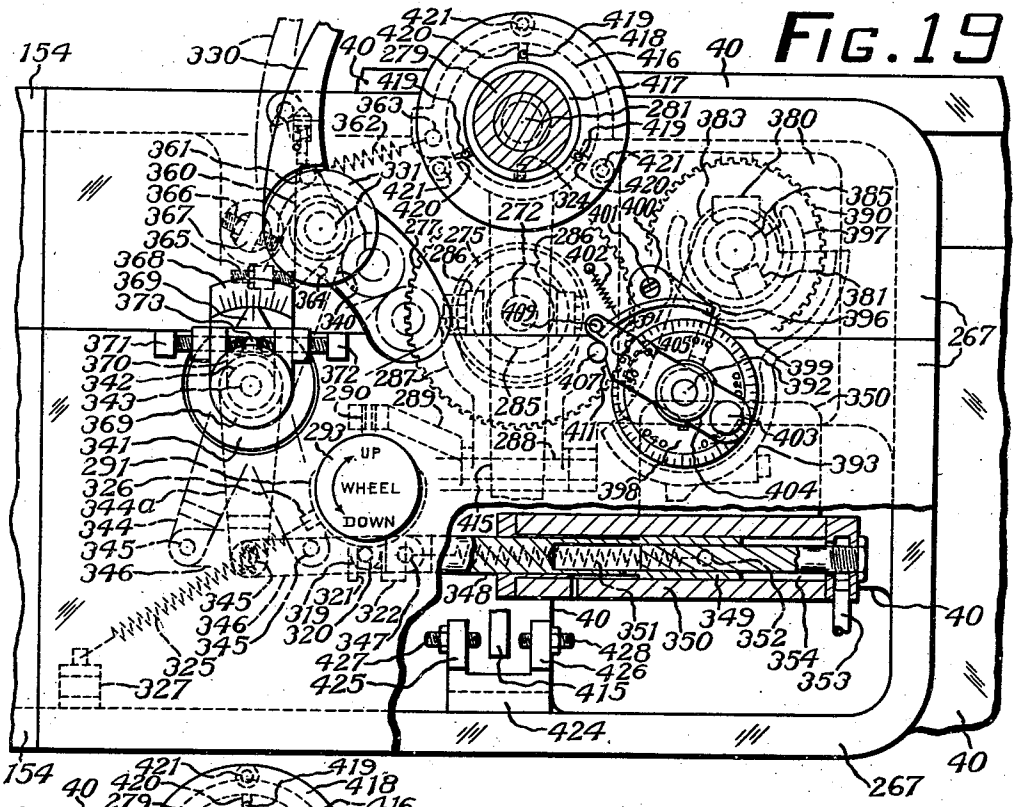
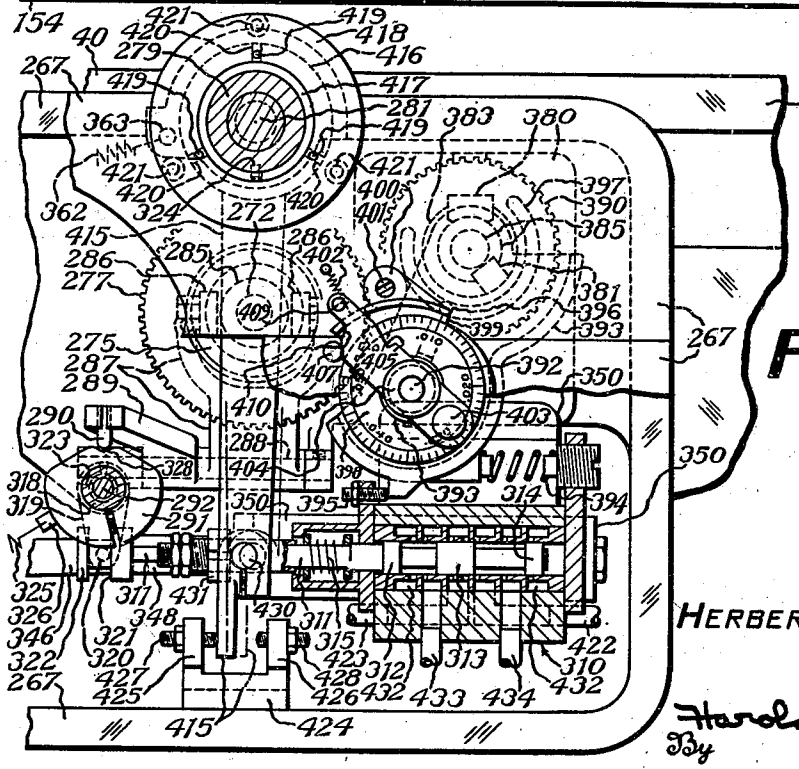


FIG. 20



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GRINDING MACHINE

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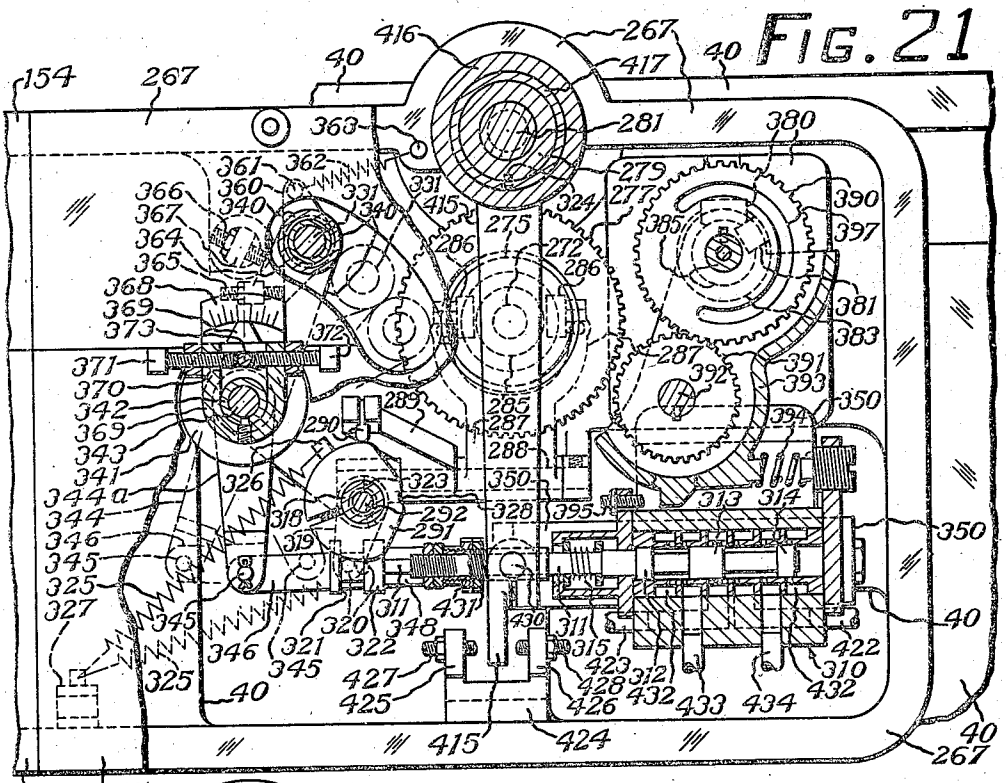
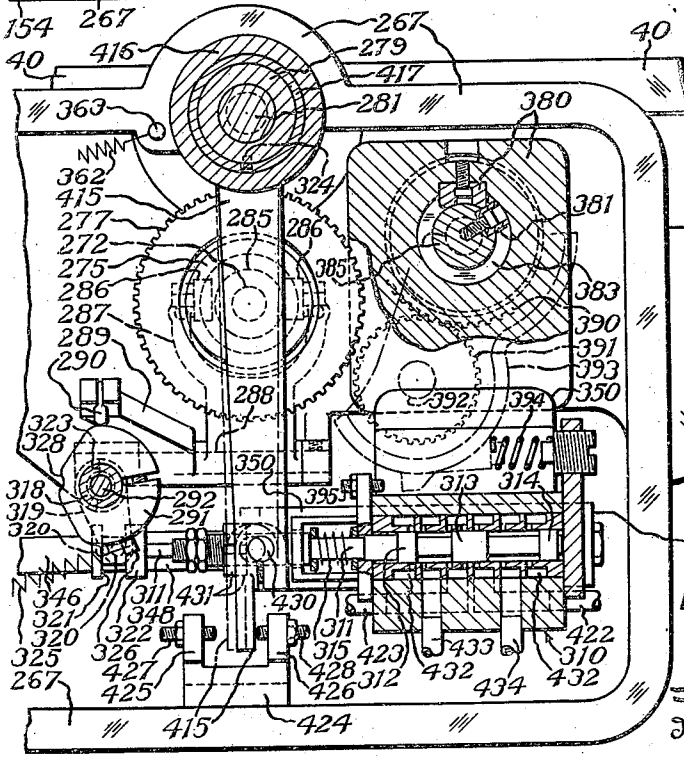
FIG. 21





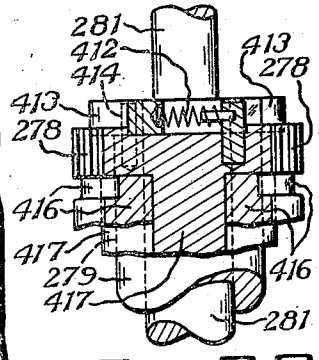


FIG. 23

FIG. 22

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Attorney

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GRINDING MACHINE

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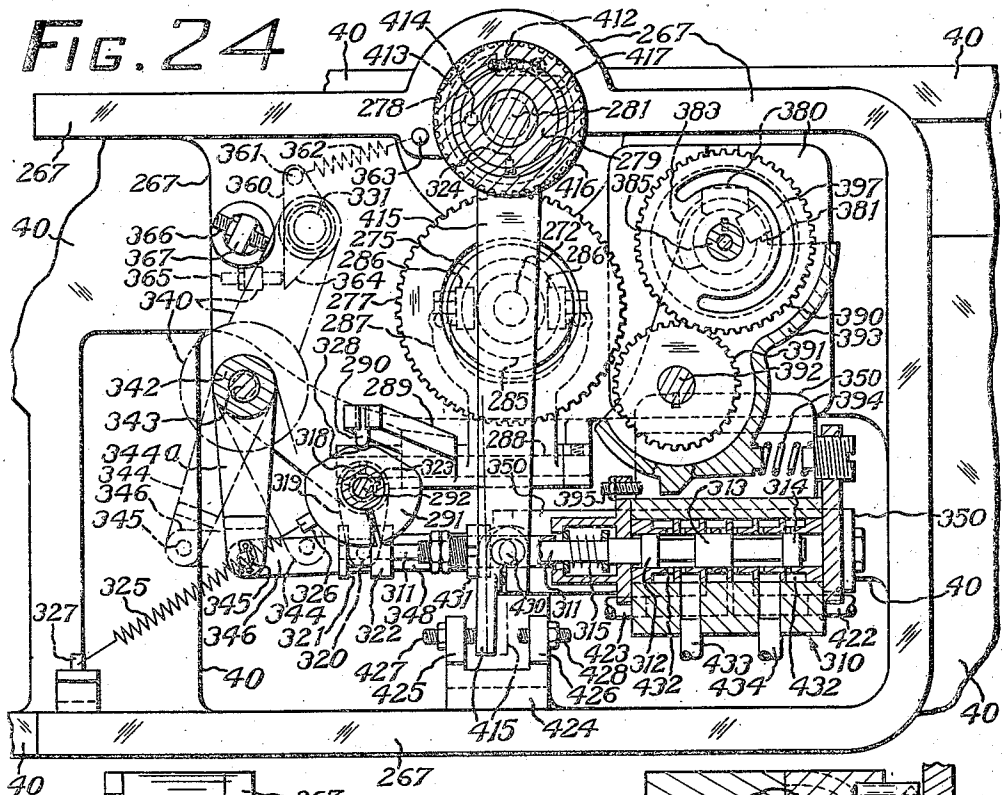
FIG. 24



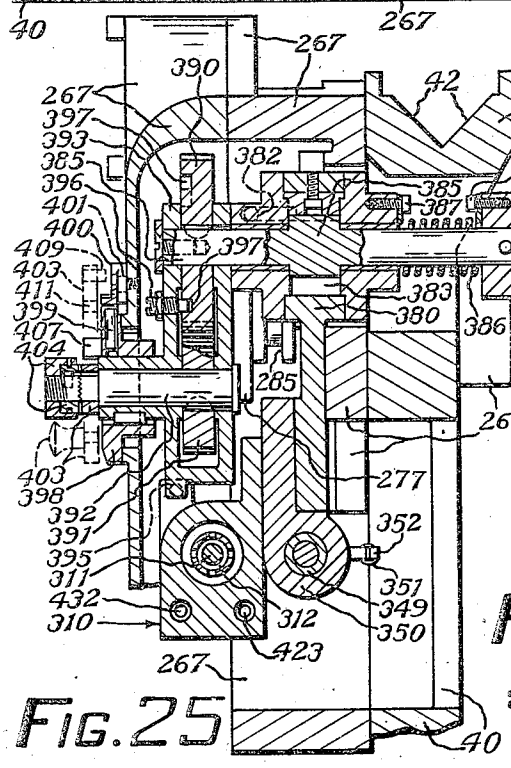


FIG. 25

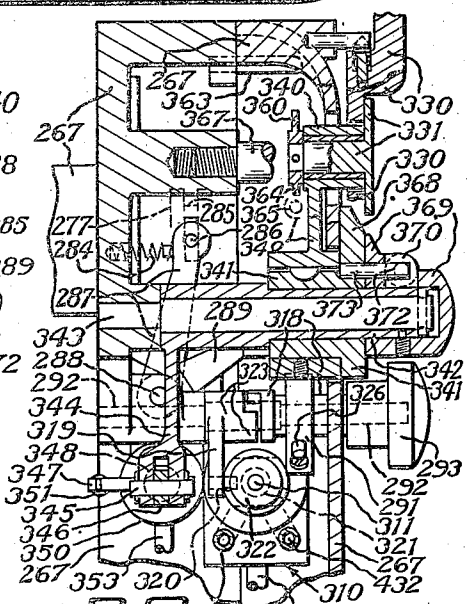


FIG. 26

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GRINDING MACHINE

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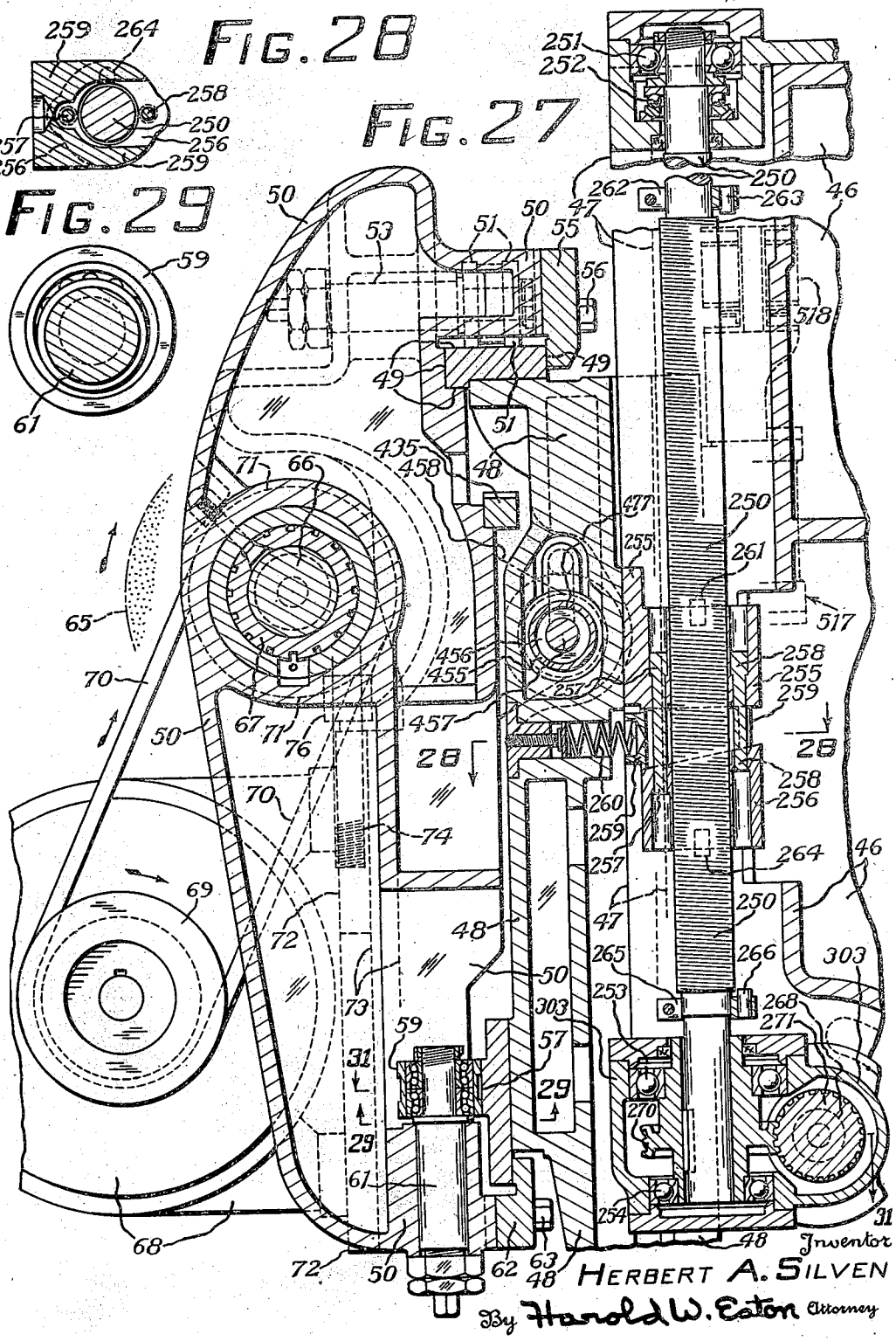
FIG. 28

FIG. 27

FIG. 29



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May 26, 1942. H. A. SILVEN 2,284,073

GRINDING MACHINE

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FIG. 30

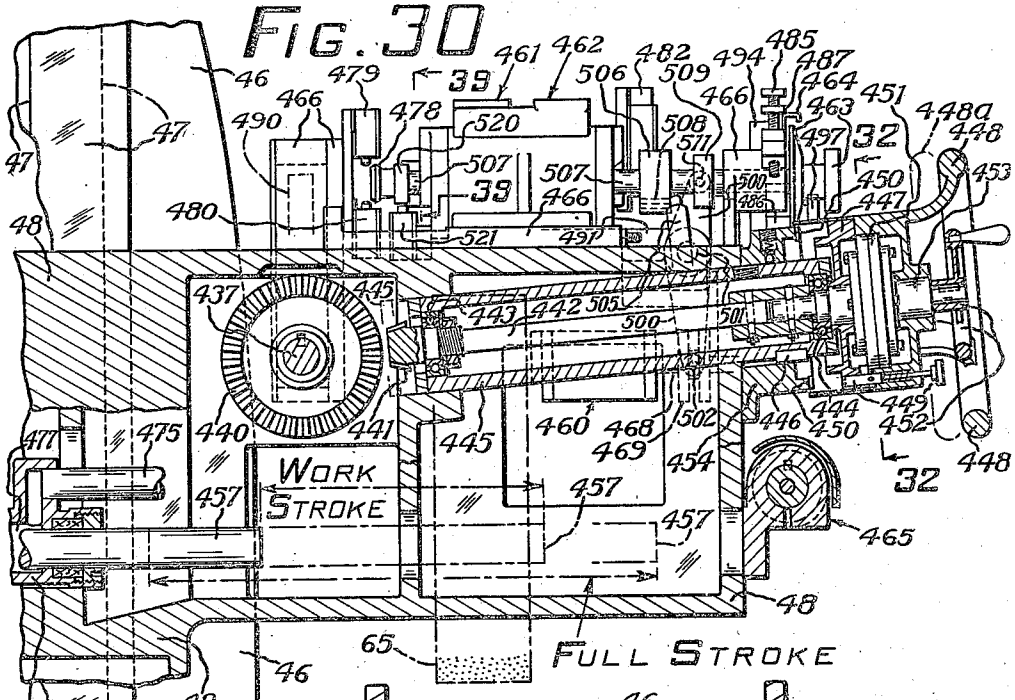
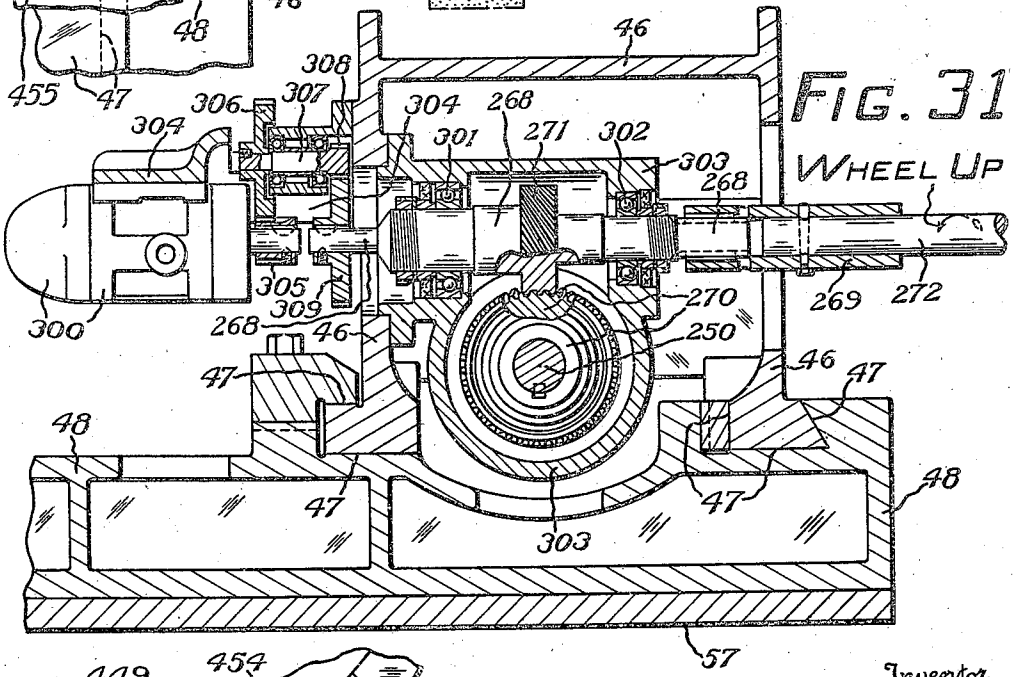


FIG. 31



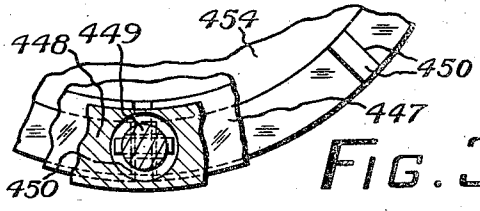


FIG. 32

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GRINDING MACHINE

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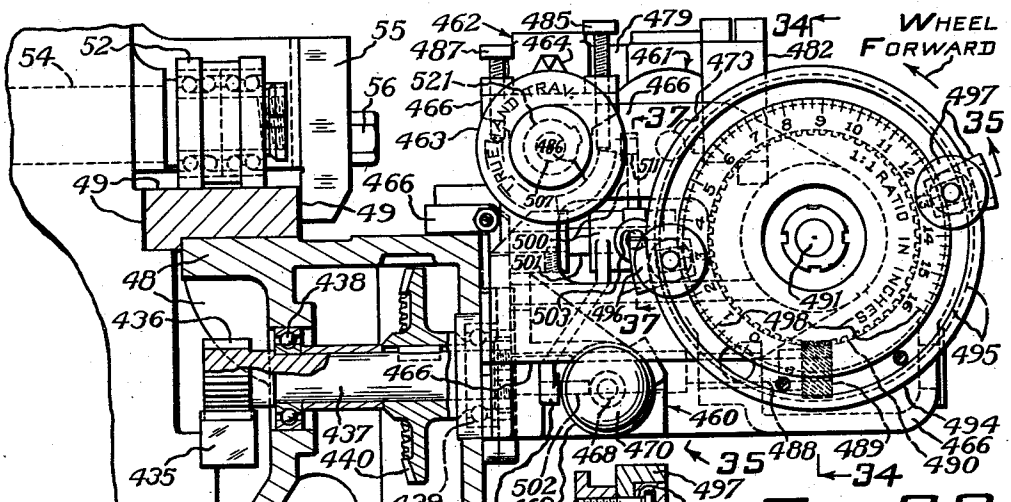

FIG. 33

FIG. 35

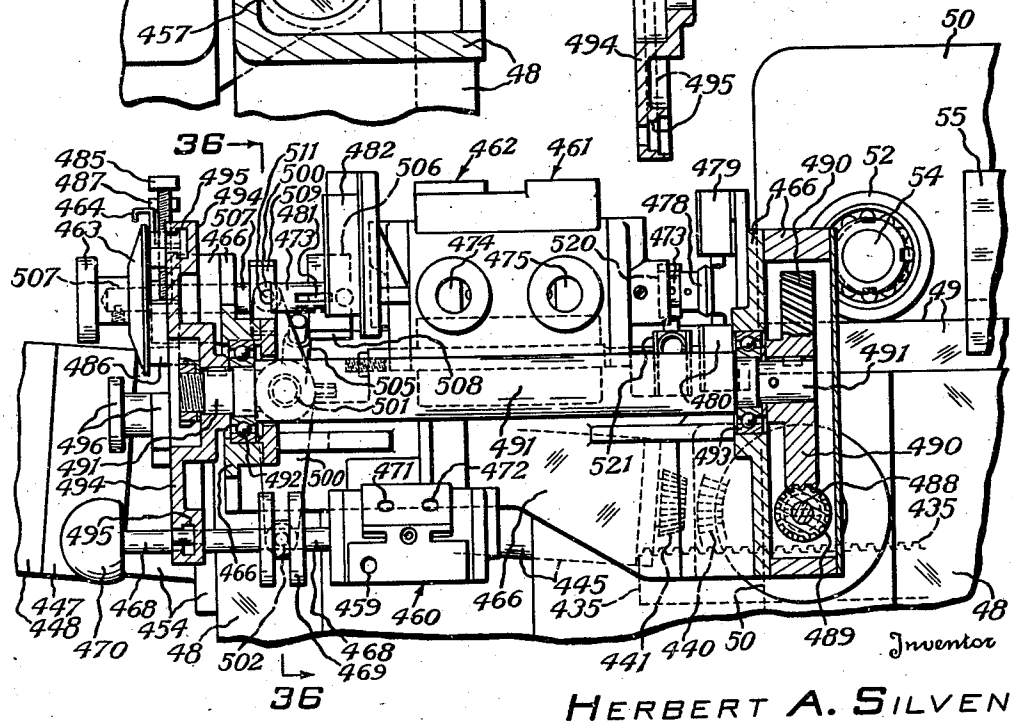

FIG. 34

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Attorney

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GRINDING MACHINE

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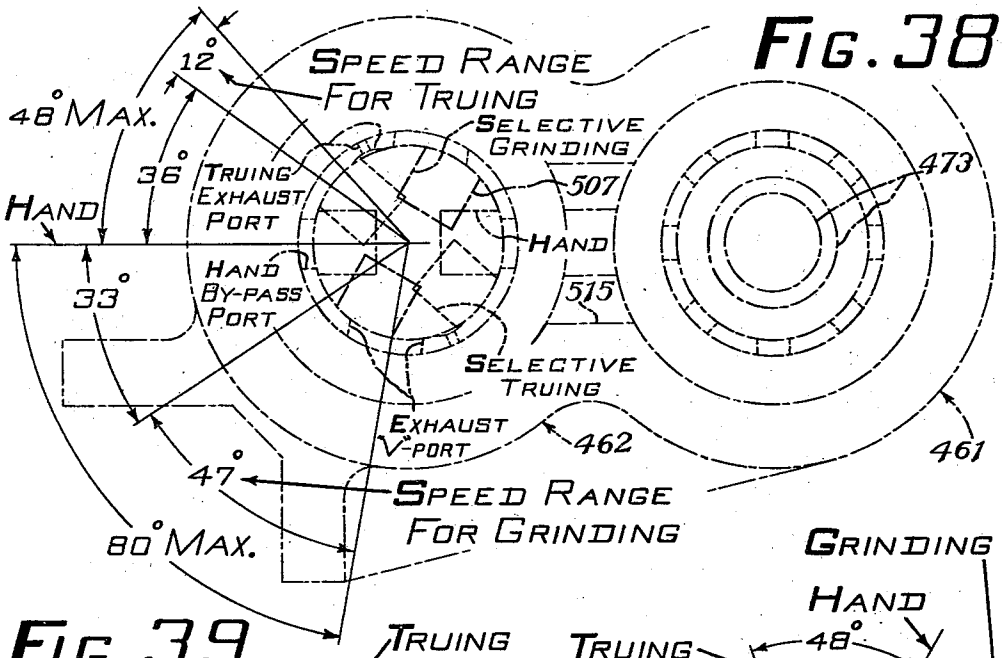

FIG. 38

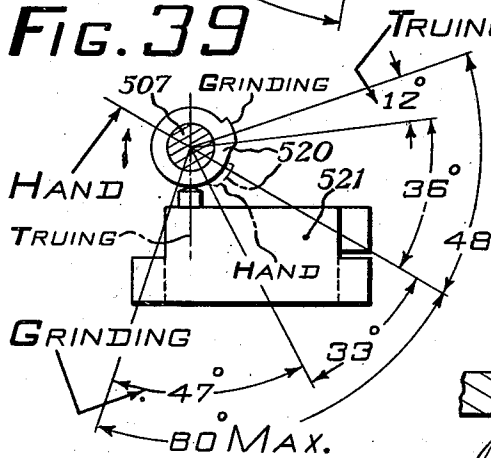

FIG. 39

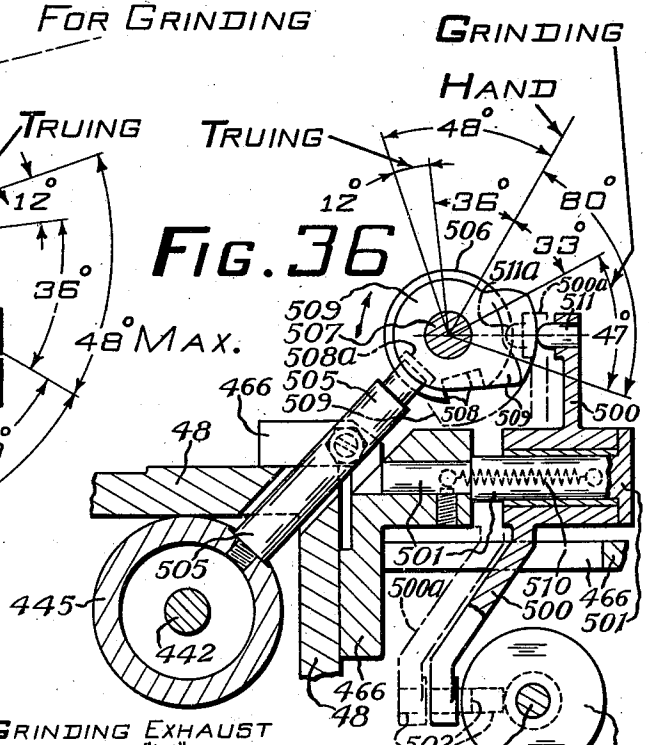

FIG. 36

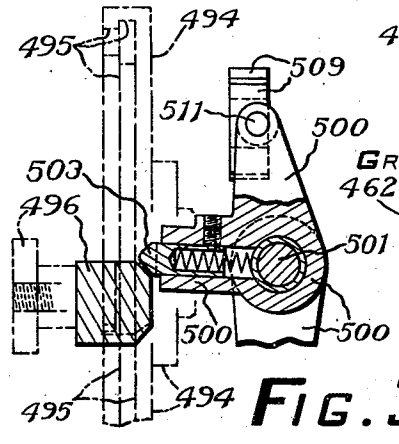

FIG. 37

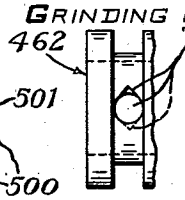

FIG. 40

HERBERT A. SILVEN

By Harold W. Eaton Attorney

Patented May 26, 1942 2,284,073

UNITED STATES PATENT OFFICE

2,284,073

GRINDING MACHINE

Herbert A. Silven, Worcester, Mass., assignor to Norton Company, Worcester, Mass., a corporation of Massachusetts

Application March 27, 1940, Serial No. 326,224

19 Claims. (Cl. 51—92)

The invention relates to grinding machines, and with regard to its more specific features to surface grinding machines.

One object of the invention is to provide a surface grinder which is automatic in operation from the time the operator has placed the work piece in position on the table until the grinding operation is finished. Another object of the invention is to provide a surface grinder in which the wheel and the work are relatively traversed, cross-fed at one or both ends of the reciprocatory traverse, and fed relatively in a vertical position after the entire surface has been covered.

Another object of the invention is to provide a surface grinder of the type just indicated with automatic instrumentalities to reposition the grinding wheel and work piece relatively in a vertical direction at the end of a grinding operation. Another object of the invention is to measure a grinding operation by the total number of complete passes over the work piece bringing the grinding operation to a close at the end of a predetermined number of such passes. Another object of the invention is to provide a counting mechanism for a grinder with a complex series of movements to determine a grinding operation at the end of a predetermined number of such movements involving traverse, cross feed, and vertical feed. Another object of the invention is to determine the grinding operation at the end of a definite number of vertical movements of the grinding wheel as measured by a counting device which can be set to count off any given number of such movements within limits.

Another object of the invention is to provide a surface grinding machine with a reciprocatory table for the work piece, a column, a vertical slide and a horizontal wheel slide for the grinding wheel, and hydraulic actuating mechanism for the table and slides with provision for manual feed or positioning of the table or any of the slides. Another object of the invention is to provide hydraulic means to return the vertical slide to initial position after a grinding operation in order to have the machine ready for the next grinding operation. Another object of the invention is to balance the weight of the vertical slide and the cross feed or wheel slide which is supported thereon hydraulically. Another object of the invention is to provide a fluid pressure system in which heat losses into the base are minimized. Another object of the invention is to provide a vertical feed controlling and actuating mechanism which is susceptible of quick and accurate control automatically and manually and designed to operate according to the objects heretofore given. Other objects will be in part obvious or in part pointed out hereinafter.

The invention accordingly consists in the features of construction, combinations of elements, and arrangements of parts, as will be exemplified in the structure to be hereinafter described, and the scope of the application of which will be indicated in the following claims.

In the accompanying drawings in which is illustrated one of many possible embodiments of the mechanical features of this invention,

Fig. 1 is a front elevation of a surface grinding machine embodying the invention, showing much of the controlling apparatus that is within the base or behind an apron in dotted lines;

Fig. 2 is a side elevation of the machine, looking from the left in Fig. 1;

Fig. 3 is a fluid pressure and wiring diagram for the machine, illustrating most of the actuating and controlling motors, cylinders and solenoids to show the complete cycle of operation and the machine control;

Fig. 4 is a fragmentary front elevation, on an enlarged scale, of the base and table of the machine, illustrating part of the reciprocatory traverse control and also the hand wheel feed for the table;

Fig. 5 is a cross-sectional view of the manually operable table traversing mechanism, taken approximately on the line 5—5 of Fig. 4;

Fig. 6 is a front elevation, on an enlarged scale, of a table stop dog;

Fig. 7 is a vertical sectional view taken approximately on the line 7—7 of Fig. 8, showing the interlock between the manual and the hydraulic table traverse mechanisms;

Fig. 8 is a fragmentary plan view of the table reversing mechanism, showing the stop and start valve in section and also the manual traversing mechanism;

Fig. 9 is a vertical sectional view taken approximately on the line 9—9 of Figs. 8 and 4;

Fig. 10 is a vertical sectional view, on an enlarged scale, of a connection between the arm on the bottom of the main reversing post and a shaft which is connected to the piston rod of the table reversing valve, the section being taken approximately on the line 10—10 of Fig. 12;

Fig. 11 is a fragmentary vertical sectional view, on an enlarged scale, taken approximately on the line 11—11 of Fig. 4, showing one of the rollers which is actuated by a table dog and its connection to a vertical rod which controls the counting

mechanism, and also illustrating a control for the speed of the table;

Fig. 12 is a fragmentary sectional view, taken approximately on the line 12—12 of Fig. 14, illustrating the feeding mechanism to feed the grinding wheel in a vertical direction;

Fig. 13 is a fragmentary vertical sectional view, on an enlarged scale, taken approximately on the line 13—13 of Fig. 14, showing the feeding mechanism for feeding the grinding wheel in a vertical direction;

Fig. 14 is a fragmentary front elevation, on an enlarged scale, of the vertical wheel feeding mechanism and the controls therefor;

Fig. 15 is a fragmentary sectional view, on an enlarged scale, taken approximately on the line 15—15 of Fig. 14;

Fig. 16 is a fragmentary sectional view taken approximately on the line 16—16 of Fig. 15;

Fig. 17 is a fragmentary sectional view, on an enlarged scale, taken approximately on the line 17—17 of Fig. 15;

Fig. 18 is a vertical sectional view taken approximately on the line 18—18 of Fig. 13;

Figs. 19, 20, 21 and 22 are all elevations of the vertical feeding mechanism, showing certain parts in section and also illustrating different positions of the same parts so that the cycle of operation may be more readily understood;

Fig. 23 is a fragmentary sectional view, on an enlarged scale, taken approximately on the line 23—23 of Fig. 18;

Fig. 24 is a view similar to that shown in Figs. 19 to 22 inclusive, showing certain parts in different positions;

Fig. 25 is a fragmentary vertical sectional view taken approximately on the line 25—25 of Fig. 18;

Fig. 26 is a fragmentary vertical section taken approximately on the line 26—26 of Fig. 14;

Fig. 27 is a fragmentary vertical sectional view, on an enlarged scale, taken approximately on the line 27—27 of Fig. 2 through the cross slide and the vertical slide, showing also part of the vertical column;

Fig. 28 is a fragmentary cross-sectional view taken approximately on the line 28—28 of Fig. 27;

Fig. 29 is a fragmentary sectional view, on an enlarged scale, taken approximately on the line 29—29 of Fig. 27;

Fig. 30 is a fragmentary vertical sectional view, on an enlarged scale, taken approximately on the line 30—30 of Fig. 1, showing the cross feeding mechanism;

Fig. 31 is a fragmentary horizontal sectional view, taken approximately on the line 31—31 of Fig. 27;

Fig. 32 is a fragmentary cross-sectional view, on an enlarged scale, taken approximately on the line 32—32 of Fig. 30;

Fig. 33 is a fragmentary front elevation of the transverse wheel feeding mechanism which is partly broken away and shown in section to clarify the illustration;

Fig. 34 is a fragmentary sectional view taken approximately on the line 34—34 of Fig. 33;

Fig. 35 is a fragmentary sectional view taken approximately on the line 35—35 of Fig. 33, showing a section through the transverse feed wheel;

Fig. 36 is a fragmentary sectional view, on an enlarged scale, taken approximately on the line 36—36 of Fig. 34;

Fig. 37 is a fragmentary sectional view, on an enlarged scale, taken approximately on the line 37—37 of Fig. 33;

Fig. 38 is a dot and dash end view of the selector valve, showing the different positions of the valve stem, that is grinding, hand and truing, and connecting body of the wheel slide reverse valve;

Fig. 39 is a fragmentary view, on an enlarged scale, taken approximately on the line 39—39 of Fig. 30; and

Fig. 40 is a fragmentary plan view, on an enlarged scale, of the sleeve in the selector valve, showing one of the V-ports for controlling the speed of the transverse indexing movement of the grinding wheel.

A surface grinding machine has been illustrated in the drawings comprising a base 40 which supports a longitudinally reciprocable work supporting table 41 on the usual V-way 42 and flat way 43 formed on the upper surface of the base 40. The base 40 supports an upwardly projecting massive column 46 (Figs. 1 and 2) which is provided with a vertically extending slideway 47. A vertically movable slide 48 is provided with ways which mate with the slideway 47 so that the slide 48 may be moved in a vertical direction. The vertically movable slide 48 is provided with a horizontally extending slideway 49 which serves as a support for a transversely movable wheel slide 50. In the preferred form an anti-friction support is provided for the wheel slide 50 which may comprise anti-friction rollers 51 and 52 (Figs. 2 and 27) which are arranged at opposite ends of the wheel slide 50 and are supported thereon by means of the shafts 53 and 54, respectively. The rollers 51 and 52 ride upon the slideway 49 and serve as an anti-friction support for the slide 50. A plate 55 which is bolted to the wheel slide 50 by means of screws 56 (Fig. 27) serves to guide the wheel slide 50 and to hold it in position upon the slideway 49.

The lower portion of the vertical slide 48 is provided with a longitudinally extending flat way 57 which serves to support and guide the lower portion of the wheel slide 50. In order to provide an anti-friction support, the wheel slide is provided with anti-friction rollers 58 and 59 (Figs. 2, 27 and 29) which are supported on shafts 60 and 61 journalled in the wheel slide. A plate 62 which is bolted to the wheel slide 50 by screws 63 serves to prevent a lifting of the wheel slide and also serves as an additional means for guiding the wheel slide during its transverse movement.

In order to facilitate adjustment of the lower sliding elements, the rollers 58 and 59 are preferably supported by an anti-friction bearing and are formed integral with the studs 60 and 61 but eccentric relative thereto. By a rotary adjustment of the studs 60 and 61, the anti-friction rollers 58 and 59 may be adjusted as desired to take up any lost motion in the lower sliding part. A pair of lock nuts are provided for the studs 53, 54, 60 and 61 which serve to clamp them in adjusted positions. Outwardly extending end portions of the studs 53, 54, 60 and 61 are formed of a square cross-sectional shape whereby the studs may be readily rotated by means of a wrench and when adjusted into the desired position may be locked by tightening the lock nuts.

The cross slide or wheel slide 50 serves as a support for a rotatable grinding wheel 65 which is supported at one end of a rotatable wheel spindle 66. The wheel spindle 66 is journalled

in suitable bearings 67 which are mounted in fixed relation with the wheel slide 50. The bearings 67 are provided with the usual adjusting devices whereby the bearing may be adjusted to compensate for wear of the parts.

The grinding wheel spindle 66 may be driven by means of an electric motor 68 which is adjustably supported on a bracket depending from the wheel slide 50 (Fig. 2). The motor 68 is provided with a multiple V-groove pulley 69 which is connected by means of a multiple V-belt 70 with a multiple V-groove pulley 71 which is mounted on the end of the wheel spindle 66.

The motor 68 is supported on a vertically adjustable plate 72 (Figs. 2 and 27) which is adjustably supported on a depending slideway 73 formed integral with the wheel slide 50. An adjusting screw 74 is rotatably supported in a bracket 75 which is fixedly mounted on the depending portion of the wheel slide 50. The screw 74 is held against endwise movement in the bracket 75 but is arranged for a rotary movement relative thereto. The screw 74 is screw threaded into a portion 76 of the supporting plate 72 so that when the screw 74 is rotated, the screw will impart a vertical adjusting movement to the plate 72 and the motor 68 to facilitate adjusting the tension of the driving belt 70.

Hand table traverse

If desired, the work supporting table 41 may be traversed longitudinally by means of a manually operable traversing mechanism (Figs. 4, 5 and 8) comprising a rack bar 80 which is fixedly mounted on the under side of the table 41. A gear 81 is mounted on the inner end of a rotatable shaft 82 which is journalled in suitable anti-friction bearings 83 and 84. The bearings 83 and 84 are supported within a slidably mounted sleeve 85 which is slidably keyed by means of a key 86 within an aperture 87 which is formed integral with an apron 88 fixedly mounted on the front of the machine base 50. A gear 89 is keyed on the left-hand end of the shaft 82 (Fig. 5). The gear 89 meshes with a gear 90 which is rotatably supported on a stud 91. The stud 91 is fixedly mounted relative to the apron 88. A manually operable traverse wheel 92 is supported to rotate with the gear 90.

The sleeve 85 is arranged for an axial sliding movement so that the gear 81 may be readily moved into or out of mesh with the rack bar 80. As illustrated in Figs. 5, 8 and 9, the gear 81 is shown as out of mesh with the rack bar 80 and is held in this position by means of a spring-pressed detent 93 (Fig. 8) which engages a V-notch 94 cut in the periphery of the sleeve 85. When it is desired to traverse the table 41 manually, the sleeve 85 is moved toward the right (Fig. 5) to shift the gear 81 from the full line position (Figs. 5 and 8) into the dotted line position 81*a* in mesh with the rack bar 80, in which position a second V-notch 95 is moved into engagement with the detent 93 to hold the sleeve 85 in an operative position.

During the normal grinding operation the table 41 is preferably traversed or reciprocated longitudinally by a hydraulically operated mechanism to be hereinafter described and the hand traverse mechanism is maintained in an inoperative position, such as that shown in Fig. 5, with the gear 81 out of mesh with the rack bar 80. The manual traverse mechanism, as above described, is preferably interlocked with the hydraulic table traverse mechanism so that manual table traverse mechanism is locked in an inoperative position during the power traverse of the table.

Hydraulic table traverse mechanism

The work table 41 is traversed or reciprocated longitudinally by means of a hydraulically operated table traversing mechanism comprising a pair of spaced parallel cylinders 100 and 101 (Figs. 1, 3 and 5). The cylinders 100 and 101 are fixedly mounted relative to the base 40. The cylinder 100 contains a slidably mounted piston 102 which is connected by means of a piston rod 103 with a bracket 104 depending from the under side of the table 41 at its right-hand end (Fig. 3). Similarly the cylinder 101 contains a slidably mounted piston 105 which is connected by means of a piston rod 106 with a bracket 107 depending from the under side of the table 41 at its left-hand end.

A table reversing valve 110 is provided to control the passage of fluid under pressure through a pipe 111 into a cylinder chamber 112 within the cylinder 101, or through a pipe 113 into a cylinder chamber 114 formed within the table cylinder 100. The reversing valve 110 is a piston type reversing valve comprising a valve stem 115 having formed integrally therewith the valve pistons 116, 117, 118, 119, 120, 121, 122 and 123.

A fluid pressure system is provided for conveying fluid under pressure to the various mechanisms of the machine, comprising a reservoir 125 (Figs. 1, 2 and 31) which is preferably formed within the box-like base 40 of the grinding machine. Fluid is pumped from the reservoir 125 by means of a motor driven fluid pressure pump 126 which draws fluid through a pipe 127 and forces the fluid under pressure through a pipe 128 into the valve chamber located between the valve pistons 120 and 121. Fluid under pressure is also simultaneously passed from the pipe 128, through the pipe 129 (Figs. 3, 9 and 12), into the valve chamber located between the valve pistons 118 and 119. In the position of the valve stem 115 (Fig. 3), fluid under pressure also enters the valve chamber between the valve pistons 117 and 118. An adjustable relief valve 130 is connected in the pipe line 128 and serves to return excess fluid under pressure to the reservoir 125. Excess fluid under pressure within the pipe 128 serves to open the relief valve 130 and exhaust excess fluid under pressure through a pipe 131 into the reservoir 125.

A second motor driven fluid pressure pump 135 is provided for pumping fluid through a pipe 136 from the reservoir 125 and forcing fluid under pressure through a pipe 137 into a valve chamber located between the valve pistons 121 and 122 and also to convey fluid under pressure from the pipe 137 through a pipe 138 into the valve chamber located between the valve pistons 117 and 118 (Fig. 3). The admission of fluid under pressure to the end chambers of the valve 110 serves to aid in shifting the reversing valve into its reverse position. The fluid pressure pump 135, in addition to conveying fluid under pressure to aid in the shifting of the table reversing valve 110, also serves to supply fluid under pressure to other fluid pressure operated mechanisms of the machine which will be hereinafter described. A relief valve 139 connected with the pipe line 137 serves to exhaust excess

fluid under pressure through a pipe 148 into the reservoir 125.

Reverse valve—actuating mechanism

A reversing lever 144 (Figs. 4, 8 and 9) is mounted on the front of the machine base. The lever 144 is formed as a bell crank lever having outwardly projecting arms 145 and 146 which serve as supports for rotatably mounted rollers 147 and 148. The reversing lever 144 is fixedly mounted on the upper end of a rock shaft 149. The shaft 149 is arranged in a substantially vertical position and is supported in bearings 150 and 151. The bearings 150 and 151 are in turn supported in a rotatable sleeve 152 which is in turn rotatably supported within an aperture 153 formed within a table reversing apron 154 which is fixedly mounted on the front of the machine base 40 (see Figs. 4, 8 and 9).

The roller 147 is rotatably mounted on the upper end of a stud 155 which is fixedly mounted relative to the reversing lever arm 145. The roller 147 is arranged in the path of a cam face 156 formed on a table dog 157 which is adjustably supported by means of a T-slot 158 formed in the front edge of the work table 41.

The roller 148 is mounted on the upper end of a vertically movable stud 159 which is slidably supported within an aperture adjacent to the end of the arm 146 of the reversing lever 144. The roller 148 is shown in its uppermost position, in which position it lies within the path of a cam face 160 formed on a dog 161 which stops the table movement toward the left (Fig. 1) after a grinding operation has been completed, to facilitate a loading operation. When the grinding cycle is started, the roller 148 is moved downwardly into position 148*a* (as shown in dotted lines in Figs. 4, 6 and 11), in which position the roller 148 lies in the path of a cam face 162 formed on the adjustably positioned reversing dog 163. It should be noted that the cam faces 156 of the dog 157 and the cam face 162 of the dog 163 are arranged to move in different horizontal planes so that there is no conflict between the actuating rollers 147 and 148, respectively.

A lever 165 is adjustably fixed to the lower end of the rock shaft 149 (Fig. 9). The other end of the lever 165 supports a stud 166 which is operatively connected in a manner to be hereinafter described to actuate the reversing valve 110. A rod 167 is supported by means of a pair of brackets 168 and 169 which are in turn fixedly supported on opposite ends of the valve stem 115. The rod 167 is arranged parallel to the valve stem 115 (Figs. 8 and 9). A lost motion connection (Fig. 10) is provided between the stud 166 and the rod 167. This connection may comprise a pair of collars 170 and 171 which are fixedly mounted on the shaft 167 (Fig. 10). A housing 172 surrounds the rod 167 and contains a compression spring 173. The compression spring 173 is located between a pair of washers 174 and 175, respectively, which are normally held in the position illustrated in Fig. 10 by means of pins passing through the rod 167. When the lever 165 is shifted to start the reversing movement of the valve 110, the shoe 166 first moves the housing 172 longitudinally to take up lost motion between the housing 172 and the collars 170 and 171. At the same time continued movement of the housing 172 compresses the spring 173. After the housing 172 takes up the lost motion between the collars 170 and 171, continued shifting movement of the lever 165 serves to shift the reversing valve stem 115 endwise to initiate a reversing of the table 41.

The reversing lever 144 is normally actuated automatically in timed relation with the table movement to control the length of the reciprocatory stroke of the table 41. If desired, in setting up the machine or for certain grinding operations, the table reversing mechanism may be manually controlled. A manually operable table control lever 180 is rotatably supported on a stud 181 (Figs. 4 and 8). A gear segment 182 which is fixedly mounted on the lever 181 meshes with a gear segment 183. The gear segment 183 is formed integral with the lower end of the stud 155 which is supported on the end of the arm 145. It will be readily apparent from the foregoing disclosure that when the manually operable table reversing lever 180 is shifted in a clockwise direction (Fig. 8) into dotted line position 180*a*, the gear segment 182, through the gear segment 183, shifts the reversing lever 144 in a counterclockwise direction, which movement is transmitted through the shaft 149 and the lever 165 manually to shift the reversing valve 110 into its reverse position. By manually shifting the lever 180 between the full line position (Fig. 8) and the broken line position 180*a*, the table 41 may be manually controlled as desired.

A suitable mechanism is provided for automatically shifting the roller 148 downwardly into position 148*a* (Figs. 4 and 11) at the start of the grinding cycle. The vertically slidable stud 159 supporting the roller 148 is provided at its lower end with an L-shaped end 185 (Fig. 4) which mates with a correspondingly shaped slot formed in the upper surface of a vertically slidable member 186. A pull type solenoid 187 mounted within the apron 154 is connected by means of a rod 188 with the member 186. The rod 188 is adjustable to facilitate setting up the mechanism as desired. The upper end of the rod 188 is provided with a head 189 which fits within a central aperture 190 formed in the lower end of the member 186. A spring 191 surrounds the rod 188 and is interposed between the head 189 and a cover plate 192 which encloses the lower end of the aperture 190. The rod 188 is normally held in an upward position by means of a spring 193 which is interposed between an adjustable member 194 carried by the rod 188 and a stud 195 (Figs. 3 and 4) which is fixedly mounted to the apron 154 which supports the member 186. It will be readily apparent from the foregoing disclosure that the spring 193 normally maintains the roller 148 in the full line position (Fig. 4). When the solenoid 187 is energized, it causes a downward movement of the rod 188 which transmits a corresponding movement through the member 186 to shift the roller 148 downwardly into position 148*a* (as shown in dotted lines in Fig. 4).

A stud 198 is threaded into the member 186 and passes through a substantially L-shaped slot 200 (Figs. 1, 4 and 11) formed in the apron 154. The vertical portion of the L-shaped slot 200 limits the vertical movement of the member 186 as the stud 198 moves between full line position 198 and dotted line position 198*a* (Fig. 11).

The spring 191 is provided to facilitate a manual lifting of the roller 148 at any time during the grinding cycle. It will be readily apparent that the operator may manually grasp the knob at the end of the stud 198 and lift it from the dotted line position 198*a* into the full line posi-

tion 198 (Fig. 11), which movement compresses the spring 191 during the vertical movement of the member 186 to raise the roller 148 from position 148a into full line position 148. This movement may be accomplished even though the solenoid 187 may be energized and a grinding cycle in process, thus facilitating the raising of the roller 148 into the position illustrated in Fig. 4 so that it will be out of the path of the cam 162 on the dog 163 as the table 41 travels toward the left to allow the table 41 to traverse beyond its normal reciprocatory stroke into a loading position. The L-slot connection between the stud 159 and the vertically movable member 186 serves to facilitate a transverse movement of the stud 159 relative to the member 186 during a shifting movement of the reverse lever 144. If desired, the roller 148 may be locked in position 148a by depressing the stud 198 so that the stud 198 follows down the vertical portion of the L-shaped slot 200, and then moving the stud 198 toward the right (Fig. 8) within the horizontal portion of the L-shaped slot 200 to latch the member 186 in a downward position. While the stud 198 is latched in a downward position, the table 41 will reciprocate through a stroke as controlled by the table dogs 157 and 163.

Start and stop valve

In order to readily control the starting and stopping of the grinding cycle, a start and stop valve 205 (Figs. 3, 8 and 9) is provided. This valve 205 is a piston type valve comprising a valve stem 206 having formed integrally therewith valve pistons 207 and 208. A pipe 209 connecting with the valve chamber located between the valve pistons 207 and 208 (Figs. 3 and 8) is connected with the pipe 111 which connects with the chamber located between the valve pistons 118 and 119 of the reversing valve 110. A pipe 210 connects the end chambers of the stop and start valve 205 with the reservoir 125 so that any fluid within these chambers may readily exhaust into the reservoir. A pipe 211 is connected at one end to the chamber located between the valve pistons 207 and 208 of the stop and start valve 205 and connects with the pipe 113 (Fig. 3). A pipe 212 is connected between the stop and start valve 205 at one end and at the other end connects with the valve chamber located between the valve pistons 119 and 120 of the reversing valve 110, so that in the position (Fig. 3) a manual traverse of the table 41 is facilitated by a by-passing of fluid between the cylinders 100 and 101.

The valve stem 206 of the stop and start valve 205 is preferably manually controlled by means of a manually operable control lever 215 (Figs. 8 and 9) mounted on the front of the machine base. The lever 215 is fixedly mounted on the upper end of the rotatable sleeve 152. An arm 216 is also fixedly mounted adjacent to the lower end of the sleeve 152 so that the lever 215, the sleeve 152 and the arm 216 function as a bell crank lever. The arm 216 is connected by a stud 217 with one end of a link 218. The other end of the link 218 is connected by means of a stud 219 with the valve stem 206. It will be readily apparent from the foregoing disclosure that when the lever 215 is moved in a clockwise direction (Fig. 8) from the full line position to the dotted line position 215a, the parts will be rocked to cause a downward movement of the valve stem 206 (Fig. 8) to shift the valve pistons 207 and 208 into a position to start the grinding cycle.

A plurality of ports 220 arranged in a staggered relationship are formed in the sleeve of the stop and start valve 205 and serve as a speed controlling device for the table 41 whereby the exhausting fluid from the table cylinders 100 or 101 may readily be controlled to regulate the speed of movement of the table 41. In order to facilitate adjustment of the valve 205 to regulate the speed, a stop mechanism is provided comprising a stop lug or pin 221 (Figs. 8 and 11) which is fixedly connected to a flange or collar 222 carried by the valve stem 206. The stop pin 221 is arranged so that it moves in the path of a rotatably adjustable stop cam 223 (Figs. 8 and 11). The cam 223 is fixedly mounted on the inner end of a rotatable shaft 224 which is rotatably supported in a bearing 225 formed within the apron 154 (Fig. 11). A combined actuating knob and dial 226 is slidably keyed to the front end of the shaft 224 which projects from the apron 154. An index point 227 (Fig. 4) is formed on the front of the apron 154 to facilitate accurate positioning of the cam to a predetermined location. A locking nut or knob 228 is screw threaded onto a threaded projecting portion of the shaft 224 by means of which the shaft 224 and cam 223 may be readily clamped or locked in adjusted position. After the cam 223 has been positioned for a predetermined grinding cycle, the valve stem 206 will be moved to the same identical position on successive grinding cycles.

At the end of the grinding cycle, when the solenoid is deenergized the roller 148 moves up to pass over the cam 162 of the dog 163 and the table 41 moves toward the left (Fig. 1). The cam 160 of the dog 161 strikes the roller 148 and shifts the reversing lever 146 and also the reversing valve 110 so that the table is ready to move toward the right. When this occurs a depending plate 245 adjustably mounted on the dog 161 has an integral cam 246 (Figs. 6, 9 and 12) which strikes a spring located finger 247 pivotally mounted in a slot in the stop and start lever 215. The finger 247 slides up the inclined left-hand face of the cam 246, rocking the lever 215 and stopping the table 41 by shifting the stop and start valve 205. The momentum of the table 41 will shift the lever 215 so that the finger 247 will clear the cam 246 (Fig. 8).

When starting another grinding cycle, the lever 215 is manually moved clockwise into position 215a so that the finger 247 will slide down the right-hand inclined face of the integral cam 246 into the dot and dash position (Fig. 8). The table 41 reciprocates to the right (Fig. 4). The dog 161 also moves to the right and the cam 246 on the plate 245 supported by the dog 161 rides over the finger 247, swinging it into the recess or groove (Fig. 8) on the lever 215. After clearing the cam 246, the tension of the spring 248 returns the finger 247 to its initial position ready for stopping the table at the end of the grinding cycle.

A cam 229 (Figs. 3 and 9) formed integral with the stud 219 which is carried by the valve stem 206 serves to close a normally open limit switch 230 when the start and stop valve is moved into a start position. The closing of the limit switch 230 serves to set in motion a fully automatic instantaneous reset electrical counter 231 such as, for example, that known as the "Microflex" instantaneous reset counter

which is manufactured by the Eagle Signal Corporation of Moline, Illinois. This "Microflex" counter is fully automatic, requiring only electrical impulses to accomplish the counting operation. The dial settings of the counter remain fixed throughout any number of cycles and need only be reset when the operator desires to change the cycle of operation of the machine.

Interlock—hand and hydraulic table traverse

It is desirable to provide an interlocking mechanism between the manually operable table traverse mechanism and the hydraulically operated table reciprocating mechanism so that the hydraulic movement of the table 41 cannot be started unless the hand traverse mechanism is in an inoperative position. A rock arm 235 (Figs. 7 and 8) is pivotally supported on a stud 236. The upper end of the rock arm 235 is connected by means of a stud 237 to one end of a link 238 (Figs. 7 and 8). The other end of the link 238 is connected by a stud 239 carried by the link 218. An arcuate slot 240 (Fig. 8) is cut through the housing surrounding the cylindrical bore 87, and into the slidably mounted sleeve 85 which supports the hand traverse mechanism for movement into and out of an operative position. When the hand traverse mechanism is in an inoperative position, that is when the gear 81 is in the full line position (Fig. 8) out of mesh with the rack bar 80, the arcuate slot 240 in the sleeve 85 is aligned with the portion of the slot 240 through the housing surrounding the sleeve 85. In this position of the hand traverse mechanism, the manually operable stop and start lever 215 may be readily opereatd to shift the start and stop valve stem 206 to start a grinding cycle.

During this shifting movement of the stop and start valve, the link 238 (Fig. 8) moves toward the right, which movement swings the rock arm 235 in a clockwise direction so that the enlarged arcuate lower end 241 of the rock arm 235 slides within the arcuate slot 240. If the hand traverse mechanism is in an operative position, that is, with the gear 81 in mesh with the rack bar 80, the start and stop lever 215 cannot be actuated due to the fact that the arcuate slot 240 in the sleeve 85 is out of line with the slot through the housing so that when the rock arm 235 is moved in a clockwise direction, the lower end 241 will engage the periphery of the sleeve 85 which serves as a stop to prevent shifting the stop and start valve 205 to start a grinding cycle. It will be readily apparent from the foregoing disclosure that an interlock is provided whereby the manually operable cycle stop and start valve 205 is rendered inoperative when the hand traverse mechanism is in an operative position. The hand traverse mechanism is similarly rendered inoperative when the stop and start valve is in an operative position.

Vertical feed

A feeding mechanism is provided for moving the slide 48 vertically to adjust the position of the grinding wheel 65 relative to the work table 41 and the work piece to be ground. This mechanism may comprise a rotatable feed screw 250 (Fig. 27) which is journalled at its upper and lower ends in anti-friction bearings 251, 252, 253 and 254 which are in turn supported in the vertically extending column 46. A nut 255 mounted on the vertically movable slide 48 meshes with the screw 250.

In order to eliminate backlash between the screw 250 and the nut 255, a second nut 256 is provided which also meshes with or engages the feed screw 250. The nuts 255 and 256 are held in alignment with each other by means of a pair of pins or studs 257 and 258 (Figs. 27 and 28) which are arranged on diametrically opposite sides of the feed screw 250. The pins or studs 257 and 258 tightly fit holes within the nut 255 and slidably engage holes formed in the nut 256 so that the nut 256 is held in alignment with the nut 255 but is free to move in an endwise or axial direction. In order to take up the backlash between the screw 250 and the nut 255, the nuts 255 and 256 are urged in opposite directions so that the thrust thereof is always in the same direction relative to the screw 250. To accomplish this result, a wedge block 259 is interposed between the nuts 255 and 256. The wedge block 259 straddles the screw 250, as will be readily apparent from the illustration in Fig. 28. A spring 260, the compression of which is adjustable by means of a screw, serves to urge the wedge block 259 toward the right (Fig. 27) to take up the backlash between the nut 255 and the screw 250.

It is desirable to provide suitable safety devices to prevent the nuts 255 and 256 from moving endwise into engagement with the bearing supports. This is preferably accomplished by means of mounting a stud 261 in the upper surface of the nut 255. A collar 262 is adjustably clamped on a reduced upper end portion of the screw 250. The collar 262 carries a stud 263 which is arranged in the path of the stud 261. If the slide 48 and the nut 255 are raised above the upper end of the screw threads on the feed screw 250, the stud 263 will rotate into engagement with the stud 261 and thus prevent further rotation of the feed screw 250.

Similarly, the lower nut 256 is provided with a stud 264. A collar 265 is adjustably clamped on the lower reduced end portion of the feed screw 250. The collar 265 carries a stud 266 which is arranged in the path of the stud 264 so that in case the slide 48 is lowered so that the nut 256 approaches the end of the threads on the feed screw 250, the stud 266 will rotate into engagement with the fixed stud 264 and thus prevent further rotation of the feed screw 250.

A spiral gear 270 (Fig. 27) is keyed on the lower end of the feed screw 250. The spiral gear 270 meshes with a spiral gear 271 which is formed integral with a shaft 268 which is connected by means of a sleeve 269 to one end of a rotatable shaft 272 (Fig. 31). The shaft 268 is rotatably supported in bearings 301 and 302 (Fig. 31) in a housing 303 which is fixedly supported on the column 46. The shaft 272 (Fig. 12) extends horizontally within the base 40 and is rotatably supported in bearings 273 and 274 in the apron 267. A clutch plate 275 is fixedly mounted on the outer end of the shaft 272. The clutch plate 275 is provided with clutch teeth which are arranged to be engaged by clutch teeth 276 formed within a cup-shaped aperture within a slidably mounted rotatable gear 277 which is rotatably supported on the shaft 272.

In the position illustrated in Figs. 12 and 14, the gear 277 meshes with a gear 278 which is supported on and keyed to the hub 279 of the index wheel 280. The index wheel 280 together with its integral hub 279 is rotatably supported on a stud 281 which is in turn fixedly mounted on the apron 267. A manually operable feed

wheel 282 is rotatably supported on the forward end of the stud 281 and is connected by means of the old and well known micrometer adjusting mechanism 283 with the index wheel 280. This micrometer adjusting mechanism will not be described in detail since this mechanism is a common expedient in cylindrical and surface grinding machines and is substantially the same as that shown in the prior U. S. Patent to Norton, No. 762,838 dated June 14, 1908, to which reference may be had for details of disclosure not contained herein. It will be readily apparent from the foregoing disclosure that in the position of the parts (Figs. 12 and 27), any rotary movement of the hand wheel 282 will be transmitted to rotate the shaft 272 and spiral gear 271 which in turn transmits a rotary movement to the gear 270 and the feed screw 250 to raise or lower the nuts 255 and 256 and thus transmit a vertical movement or adjustment to the slide 48 to raise or lower the grinding wheel 65 as desired.

A manually controlled means is provided for disconnecting the clutch teeth 275 and 276. The hub of the gear 277 is provided with a groove 285 which is engaged by a pair of diametrically opposed studs 286 carried by the yoked end of a lever 287. The lever 287 is pivotally supported on a stud 288. A lever 289 is also supported on the stud 288 and is preferably formed integral with the lever 287, the levers 287 and 289 operating as a bell crank lever. The forward end of the lever 289 is provided with a follower 290 (Figs. 12 and 13) which is arranged to engage a cam 291 which is rotatably supported on a shaft 292. A knob 293 serves to rotate the cam 291 so as to rock the bell crank levers 287—289 to move the gear 277 toward the right (Fig. 12) against compression of the spring 284 (Fig. 13) to disengage the clutch teeth 275—276, thereby disconnecting the hand wheel 282 during a power lifting of the grinding wheel 65 and vertically movable slide 48.

Hydraulically operated lift for grinding wheel slide

The wheel side assembly, that is, the vertical slide 48 and the transversely movable wheel slide 50 carried thereby, are heavy, massive parts which would require considerable exertion on the part of the operator to raise and lower the same manually. It is desirable, therefore, to provide a power operated lifting mechanism which in the preferred form comprises a fluid motor 300 (Figs. 3 and 31). The fluid motor 300 is supported by a bracket 304 which is also fixedly supported on the rear of the column 46. The fluid motor 300 is preferably a rotary type motor such as, for example, that manufactured by Sundstrand Machine Tool Company, of Rockford, Illinois. The rotor shaft of the motor 300 is provided with a gear 305 which meshes with a gear 306 supported at one end of a rotatable shaft 307. The shaft 307 is rotatably supported by a bracket mounted on the column 46. The shaft 307 is provided with a small gear 308 at its other end which meshes with a gear 309 which is keyed to the end of the shaft 268 supporting the spiral gear 271 (Fig. 31).

A control valve 310 is provided to control the admission of fluid under pressure to the fluid motor 300. The valve 310 (Figs. 18, 20, 21, 22 and 24) is preferably a piston type valve comprising a valve stem 311 having formed integrally therewith valve pistons 312, 313 and 314. The valve 310 is normally held in a central or neutral position by means of a spring 315.

The shaft 292 is preferably fixedly mounted in the apron 267 (Fig. 13). The shaft 292 supports a rotatable sleeve 312 to which is fixed the knob 293 and the cam 291. The shaft 292 also rotatably supports a downwardly extending arm 319. The arm 319 carries a stud 320 which engages a groove 321 formed in a spool-shaped member 322 which is carried on the outer end of the valve stem 311. A lost motion connection is provided between a projection on the hub 323 of the lever 319 and the inner end of the sleeve 318. This lost motion connection is provided with sufficient lost motion so that when the knob 293 is rotated to cause an upward or downward movement of the wheel slide assembly, the cam 291 will rock the bell crank lever 289—287 to disengage the clutch teeth 275—276 before the valve stem 311 is shifted to initiate a vertical movement of the wheel slide assembly.

A tension spring 325 is connected between a stud 326 supported in the periphery of the cam 291 and a stud which is carried by a bracket 327 fixed on the apron 267 which is fixedly mounted with respect to the base 40. The spring 325 normally tends to hold the cam 291 in position with the stud 290 engaging a notch 328 in the periphery of the cam 291 (Fig. 18), in which position the valve 310 is in a neutral or central position and the clutch 275—276 is in operative engagement so that a rotary movement of the hand wheel 282 will be transmitted through a key and keyway construction to rotate the gear 278 which in turn transmits a rotary movement to the gear 277 and also to the shaft 272. When the knob 293 is rotated in a clockwise direction (Fig. 18) to rotate the cam 291 also in a clockwise direction into the position illustrated in Fig. 21, the bell crank lever 289—287 first disengages the clutch teeth 275—276 to disengage the hand wheel 282, after which the stud 320 on the downwardly extending arm 319 shifts the valve stem 311 toward the left to shift the valve 310 into the position shown in Fig. 21 to admit fluid under pressure to the fluid motor 300. Rotation of the motor 300 serves through the gear mechanism above described to rotate the vertical feed screw 250 to raise the wheel slide assembly in a vertical direction. As soon as the operator releases his grasp on the knob 293, the released tension of the spring 325 will rotate the cam 291 in a counterclockwise direction (Fig. 21) until the stud 290 engages the notch 328, thus returning the valve 310 into a neutral position (Fig. 18) and again connecting the clutch teeth 275—276.

Similarly when the knob 293 is rotated in a counterclockwise direction to shift the cam 291 also in a counterclockwise direction, the bell crank lever 289—287 first disengages the clutch parts 275—276 and then, through the arm 319 and stud 320, moves the valve stem 311 toward the right (Fig. 22) to admit fluid under pressure to rotate the fluid motor 300 in the reverse direction. The fluid motor 300, through the gear connections above described, in turn rotates the feed screw 250 in the reverse direction to cause a downward feeding movement of the grinding wheel assembly. Similarly when the operator releases his grasp on the knob 293, the released tension of the spring 325 again rotates the cam 291 in a clockwise direction (Fig. 22) until the stud 290 engages the notch 328 in the periphery of the cam 291, during which move-

ment the valve 310 is again shifted into a central or neutral position (Fig. 18) and the clutch parts 275—276 are again engaged.

It will thus be seen that when it is desired to raise or lower the grinding wheel 65 through a considerable distance in setting up the machine, a raising or lowering movement may readily be obtained by actuation of the control knob 293. Turning the knob 293 in a clockwise direction (Fig. 1) shifts the parts to start the fluid motor 300 to rotate the screw 250 and raise the grinding wheel assembly. Rotation of the knob 293 in a counterclockwise direction serves to start the fluid motor 300 in the reverse direction to lower the grinding wheel assembly.

Automatic down feed

In order that the improved surface grinding machine may be automatic in its cycle of operation, it is desirable to provide an automatic down feeding mechanism whereby the grinding wheel 65 may be incrementally and automatically fed downwardly after the grinding wheel has been traversed completely across the reciprocating work piece to remove an additional amount of material from the surface of the work piece being ground during the next traverse of the grinding wheel 65 across the work as the work is reciprocated. A pivotally mounted feed arm 330 (Fig. 14) is pivotally supported by a stud 331. The feed arm 330 supports a small gear 332 which is arranged to mesh with the gear 280 of the feed mechanism above described. The gear 332 is formed integral with a stud 333 which is rotatably supported by a sleeve 335. A ball clutch 334 is also supported on the stud 333 and is fixedly mounted relative to the gear 332. The arm 330 is arranged to be moved in an arcuate path in a manner to be hereinafter described. The ball clutch 334 is arranged so that when the arm 330 moves upwardly, the gear 332 rotates idly in mesh with the gear 280 which is associated with the feed wheel 282. On the downward movement of the arm 330, the ball clutch 334 locks the gear 332 with respect to the arm 330 and prevents rotation thereof so that the downward movement of the arm 330 serves to impart a rotary movement to the gear 280, thus transmitting a feeding movement through the gear mechanisms above described to rotate the feed screw 250 and thereby cause a downward feeding movement of the grinding wheel 65.

The sleeve 335 which surrounds the ball clutch 334 is provided with a projecting portion or shield 336 which surrounds a portion of the gear 332. The shield 336 is cut out on one side so as to allow the gear 332 to project and mesh with the gear 280 (Figs. 15, 16 and 17). The portion 336 of the sleeve 335 serves as a guard whereby the gear 332 may be held out of mesh with the gear 280. A clamping or binding screw 337 passes through an elongated slot 338 formed in the hub portion of the arm 330 and is screw threaded into the sleeve 335. By tightening the screw 337 (Fig. 15), the sleeve 335 may be locked with respect to the arm 330. If it is desired to disconnect the incremental automatic down feed, the screw 337 is loosened and swung in a counterclockwise direction into the dotted line position 337 (Fig. 17), which movement swings the shield 336 of the sleeve 335 so that it surrounds the operative portion of the gear 332 and thus holds it out of mesh with the feed gear 280. The screw 337 may be locked in this position to prevent downward incremental automatic feeding movement of the grinding wheel 65 when desired.

The stud 331 passes through an arcuate slot (Figs. 19 and 26) formed in the apron 267 and is rotatably supported in a suitable bearing formed in the upper end of an arm 340 (Fig. 26). The arm 340 is keyed to a sleeve 341 which is in turn rotatably supported on a rotatable sleeve 342. The sleeve 342 is rotatably mounted on a stud 343 which is fixedly supported by the apron 267. The sleeve 342 is provided with an integral downwardly extending arm 344 which is connected by means of a stud 345 (Figs. 19 and 26) to a link 346. The other end of the link 346 is connected by a stud 347 to one end of a piston rod 348 (Fig. 19). A piston 349 is formed integral with the other end of the piston rod 348. The piston 349 is slidably mounted within a fluid pressure cylinder 350 which is fixedly mounted within the apron 267. A tension spring 351 located outside the cylinder 350 is connected between a stud 352 fixedly mounted on the casing of the cylinder 350 and the stud 347. The tension spring 351 serves normally to maintain the arm 344 in position 344*a*. With the lever 344*a* in the position shown (Fig. 19), the stud 331 and its supporting arm 340 are positioned at the upper end of its stroke.

When it is desired to impart a downward feeding movement to the grinding wheel 65 in timed relation with the cycle of operation, fluid under pressure is admitted through a pipe 353 into a cylinder chamber 354 (Fig. 19) to move the piston 349 toward the left, which movement serves to rock the arm 344 in a clockwise direction from position 344*a* into position 344 (Fig. 19), which movement rocks the arm 340 also in a clockwise direction. This movement produces a downward arcuate movement of the lever 330 with the gear 332 in mesh with the feed gear 280 which imparts a rotary movement to the feed screw 250 so as to produce a downward feeding movement of the grinding wheel assembly.

In order to maintain the gear 332 in operative engagement with the feed gear 280 during the arcuate oscillating movement of the arm 330, the stud 331 is provided at its inner end with a lever 360. The lever 360 is pinned to the stud 331 (Fig. 26) and is provided at its upper end with a stud 361. A spring 362 is connected between the stud 361 and a stud 363 mounted on the apron 267 (Fig. 19). The spring 362 is a tension spring and normally tends to rock the lever 360 and the arm 330 in a clockwise direction so as to maintain the gear 332 in operative mesh with the feed wheel 280 during the normal operation of the machine. The arm 360 is provided with a downwardly extending portion 364 which is arranged to engage an adjustably positioned stop screw 365 which is carried by the lever 340.

The adjustable stop screw 365 is provided for the purpose of rocking the arm 330 in a counterclockwise direction to throw the pawl gear 332 out of engagement with the ratchet wheel 280 at the upper end of its idle stroke so as to permit a manual adjustment of the vertical slide at the start of a grinding operation. By adjusting the screw 365, as the lever 340 swings in a counterclockwise direction during the idle stroke of the pawl, it will engage the lever 364 and rock the pawl gear 332 into an inoperative position before the stop screw 366 limits the upward movement of the arm 330. This mechanism automatically

renders the feed pawl inoperative at the upper end of its idle stroke so that when the surface grinding machine is started as the work table moves to bring the work piece into position beneath the wheel, the wheel may be adjusted vertically by rotation of the manually operable feed wheel 282 to bring the grinding wheel into grinding contact with the surface of the work piece without delay. This feature is important due to the fact that many types of work pieces coming to the surface grinder are of irregular thicknesses.

An adjustable stop screw 366, which is supported by a stud 367 on the apron 267, is arranged in the path of the lever 340 and serves to limit its rocking movement in a counterclockwise direction, thus limiting the upward arcuate swinging movement of the lever 330 and the gear 332.

In order to vary the extent of down feeding movement at each actuation of the feed arm 330, it is desirable to provide a suitable adjusting mechanism, whereby the effective stroke of the arm 330 and gear 332 may be adjusted as desired. The sleeve 341 has an upwardly extending integral flanged portion 368 which has a graduated scale thereon (Figs. 14 and 21). The inner sleeve 342 (Figs. 21 and 26) is provided with a knob 369 at its outer end. The knob 369 is provided with a cut-out portion forming a substantially U-shaped cross-sectional area 370 (Fig. 21) which serves as a support for a pair of opposed adjusting screws 371 and 372. The adjusting screws 371 and 372 are arranged to engage a stud 373 which projects from and is fixedly supported by the sleeve 341 and the graduated flange 368. It will be readily apparent from the foregoing disclosure that by manipulation of the screws 371 and 372 (Figs. 14 and 21), the lever 344 may be adjusted relative to the arm 340 so as to vary the extent of swinging movement of the arm 340 and thereby vary the feeding movement of the arm 340 and thereby vary the feeding movement of the feed arm 330 and the gear 332. The arm 340 always moves up into engagement with the adjustable stop screw 366, thus limiting the up movement of the feed arm 330 and the gear 332. The adjustment is facilitated by the opposed screws 371 and 372 and serves to adjust the arm 344 relative to the arm 340 so as to shift the position of the piston 349 and thereby vary the length of stroke of the feed arm 330.

Automatic lift—grinding wheel

In order that the grinding cycle may be automatic in operation, it is desirable to provide an automatically actuated mechanism automatically to raise the grinding wheel 65 to a starting position after a predetermined grinding operation has been completed. A wheel lifting mechanism is provided comprising a rotary single vane type motor 380 (Figs. 2 and 22) having a rotor shaft 385 which supports a single vane 381. When fluid under pressure is admitted through a pipe 382 (Fig. 3) into a motor chamber 383, the vane 381 will be moved in a counterclockwise direction by fluid under pressure into the position shown in Figs. 3 and 22. The rotor shaft 385 of the motor 380 is operatively connected in a manner to be hereinafter described to rotate the feed screw 250 so as to lift the grinding wheel 65 into its starting position so that it is ready for the next grinding cycle. During the operative stroke of the motor 380, any fluid within the motor on the opposite side of the vane 381 may exhaust through a pipe 384 (Fig. 3) into the reservoir 125.

A spring actuated mechanism is provided for returning the fluid motor 380 to its initial position. This mechanism comprises a helical spring 386 (Fig. 25) which surrounds the shaft 385. One end of the spring 386 is fastened by means of a screw 387 to a fixed part of the housing surrounding the motor 380. The other end of the spring 386 is fastened by means of a screw 388 to a collar 389 which is fixedly mounted on the right-hand end of the shaft 385 (Fig. 25). It will be readily apparent from the foregoing disclosure that during the fluid pressure actuation of the motor vane 381, the spring 386 will be wound up. As soon as the pressure within the pipe 382 is relieved, the released tension on the spring 386 will rotate the shaft 385 in the reverse direction to return the fluid motor to its initial position.

The rotor shaft 385 of the fluid motor 380 supports a gear 390 at its left-hand end (Fig. 25). The gear 390 is keyed to the shaft 385 and meshes with a tumbler gear 391. The tumbler gear 391 is keyed to a rotatable shaft 392 which is journalled in a pivotally mounted tumbler gear frame 393. The tumbler gear frame 393 is rotatably supported by the shaft 395 (Fig. 25). A spring 394 is interposed between the tumbler gear frame 393 and a screw stud which is fixed to the apron 267 and serves to exert a pressure against the tumbler gear frame 393, tending to move the frame 393 in a clockwise direction (Fig. 24). An adjustable stop screw 395 (Fig. 24) is provided to limit the rocking movement of the frame 393 in a clockwise direction (Fig. 24). When the tumbler gear 391 is swung in a clockwise direction into mesh with the gear 277, and the gear 390 is rotated, a rotary motion will be transmitted to rotate the feed screw 250 to raise the grinding wheel 65 by an amount equal to the down feed during the grinding cycle so as to reset the grinding wheel for grinding the next work piece.

The tumbler gear frame 393 carries a stop screw 396 having a cylindrical end portion which rides within an arcuate groove 397 formed in the side face of the gear 390 (Fig. 25). When the gear 390 is rotated in a counterclockwise direction (Fig. 24) by fluid under pressure within the vane motor 380, the rotary movement of the gear 390 is transmitted through the tumbler gear 391 to rotate the gear 277 and, through the wheel feed gearing, to rotate the feed screw 250 to raise the grinding wheel 65 until the end of the arcuate groove 397 engages the screw 396 (Fig. 18), and continued rotation of the gear 390 serves to rock the tumbler gear frame 393 in a counterclockwise direction to throw the tumbler gear 391 out of mesh with the gear 277 and thus stop the lifting movement of the grinding wheel 65, with the grinding wheel in position for starting the next grinding cycle.

A flanged member 398 is keyed to a hub projecting from the tumbler gear frame 393. The flanged member 398 supports an upwardly extending pin or stud 399 (Fig. 25). When the gear 390 rotates so that the screw 396 throws the tumbler gear frame 393 into an inoperative position, a stop pawl 400 (Fig. 18) which is pivotally mounted on a stud 401 carried by the apron 267 serves to hold the tumbler gear 391 and its supporting frame 393 in an inoperative position. A spring 402 exerts a tension on the pawl 400 tending to rock it in a counterclockwise direction to

hold it in a latched position in engagement with the stud 399.

The shaft 392 supports a control arm 403. This arm is rotatably supported on a reduced end portion of the shaft 392 and is connected to rotate with the shaft by means of a clutch member 404 having clutch teeth which engage clutch teeth formed on the lever 403. The lever 403 may be rotatably adjusted relative to the shaft 392 by moving the clutch member 404 toward the left (Fig. 25) to disengage the clutch teeth and then the lever 403 may be rotated into the desired position so that the index surface 405 on the lever 403 is aligned with the desired graduation on the scale formed on the flanged member 393. At the start of a grinding cycle when the stop and start valve 205 is shifted to start the cycle of operation, fluid is exhausted from the fluid motor 380, and the released tension of the spring 386 rotates the shaft 392 and the lever 403 from the position illustrated in Fig. 14 in a counterclockwise direction. The lever 403 continues its counterclockwise movement until the lever 403 engages a stop pin or stud 407 which is fixedly mounted on the apron 267 (Fig. 20). Just before the lever 403 reaches the position illustrated in Fig. 19, a pin or stud 409 carried at the end of the lever 403 engages a cam surface on the pawl 400 and rocks the pawl out of engagement with the stud 399, thus releasing the latch which holds the tumbler gear frame 393 in an inoperative position.

At the same time the pawl 400 is released from the stud 399, a circular depression 410 (Fig. 19) on the lever 403 engages the stud 407 so that the stud 407 together with the lever 403 holds the tumbler gear frame 393 in an inoperative position during a grinding operation. The parts remain in position (Fig. 19) until the end of a grinding cycle is reached and the stop and start valve 205 is shifted to a stop position (Figs. 3 and 9), at which time fluid under pressure is admitted through the pipe 382 into the motor chamber 383 to move the rotor vane 381 in a counterclockwise direction into the position illustrated in Figs. 3 and 22. As the vane motor starts its rotation, it transmits a counterclockwise rotary movement to the gear 390 which in turn transmits a clockwise rotary movement to the tumbler gear 391. Clockwise rotary movement of the gear 391 rotates the shaft 392 and starts the movement of the lever 403 in a clockwise direction. As the depression 410 of the lever 403 moves away from the stud 407 (Figs. 19 and 20), the released compression of the spring 394 causes the cam face 411 on the lever 403 to ride along the pin 407 to gradually allow the tumbler gear frame 393 to rock in a clockwise direction to throw the tumbler gear 391 into mesh with the gear 277. Continued rotation of the vane motor 380 and gears 390—391 transmits a rotary motion to the gear 277 to rotate the feed screw 250 to raise the grinding wheel slide assembly in a vertical direction to return the grinding wheel 65 to a starting position ready for the next cycle of operation.

Manually operable lift mechanism

A manually operable lifting mechanism is provided for raising and lowering the grinding wheel slide assembly. Due to the massive, heavy wheel slide assembly, it is desirable to provide a manually operable mechanism which is arranged so that the wheel slide assembly may be raised and lowered without undue effort on the part of the operator. The manually operable feed wheel 282 is utilized to rotate the feed screw 250. In order to provide an easily operated mechanism, the fluid motor 300 together with the control valve 310 are utilized to overcome part of the weight of the massive heavy wheel slide assembly. The valve 310 is operatively connected in a manner to be hereinafter described so that when the hand wheel 280 is rotated to cause a lifting movement of the grinding wheel 65, the valve 310 will be partially opened to admit a supply of fluid under pressure to the fluid motor 300, the fluid under pressure admitted to the motor 300 being such that the motor has not sufficient power to rotate the feed screw 250 to lift the grinding wheel slide assembly. The mechanism, however, is arranged so that only a slight amount of manual power is required on the hand wheel 282 to supplement the fluid motor 300 to readily rotate the feed screw 250 under manual control to lift the grinding wheel assembly to the required extent. This mechanism is preferably arranged so that the fluid motor 300 is utilized to supplement the manual rotation of the hand wheel 282 only on the upward movement of the slide, it being unnecessary on the down movement.

A vertically extending lever 415 is provided with an enlarged hub portion 416 at its upper end which surrounds and is rotatably supported on a hub 417 formed integral with the gear 278 (Fig. 12). A friction plate 418 also surrounds the hub 417 and is interposed between the feed gear 280 and the hub portion 416 of the lever 415. A plurality of spaced pins 419 carried by the friction plate 418 engage radially extending slots 420 so that the friction plate 418 and hub portion 416 of the lever 415 will turn together with respect to the supporting hub 417. A plurality of spring-pressed balls 421 are provided in a fixed part of the apron 267. The spring-pressed balls 421 engage the base of the friction plate 418 and hold it in frictional engagement with the feed gear 280 so that when the hand wheel 282 is rotated to rotate the feed gear 280 and transmit a rotary motion to the shaft 272 and the feed screw 250, a rotary motion will be imparted through the friction plate or disk 418 and the hub portion 416 to swing the lever 415 either in a clockwise or counterclockwise direction (Figs. 19 and 20) depending upon the direction of rotation of the hand wheel 282.

When the hand wheel 282 (Fig. 14) is rotated in a counterclockwise direction, the index wheel 280 moves the friction plate 418 and swings the lever 415 until its lower end contacts the stop screw 428. This occurs when the feed gear 280 is rotated manually or the arm 330 feeds the grinding wheel down, as the fluid motor 300 is not required to assist the lowering of the heavy wheel slide assembly, as gravity aids the operator and also the automatic wheel feeding mechanism. Consequently the key 324 engages its lost motion keyway on the righthand side (Fig. 18) so that the gear 278 which mounts the key 324 will immediately feed the grinding wheel 65 down for another grinding pass or stock removal. In this case, the valve stem 311 is not moved and also there is no relative movement between the feed gear 280 and the gear 278. Consequently the spring 412 is not compressed but remains in a neutral position and the lever 415 is maintained in contact with the screw 428 during the feeding of the grinding wheel down at the end of the cross pass.

A substantially U-shaped bracket 424 is either formed integral with or fixedly mounted to the

apron 267 and is provided with two upwardly extending spaced arms 425 and 426 which serve as supports for a pair of opposed adjustable stop screws 427 and 428. The stop screws 427 and 428 are arranged in the path of movement of the lever 415 and serve to limit its movement either in a clockwise or counterclockwise direction.

In case the operator desires to manually raise the wheel slide assembly at the start of a grinding cycle to offset the amount of stock removal on the first cross pass of the grinding wheel 65, the hand wheel 282 is rotated clockwise. The feed gear 280, through the friction plate 418, will rock the lever 415 without rotating the gear 278 which would raise the heavy wheel slide assembly, requiring great exertion by the operator if a lost motion keyway was not used for mounting the key 324. This is accomplished by a keyway wider than the key 324 (Fig. 18). This lost motion is not taken up until the lever 415 strikes the screw 427 and has shifted the valve stem 311 so that the fluid motor 300 will act as a booster and assist the operator to raise the massive grinding wheel assembly.

In this movement of the lever 415, the gear 278 does not move but compresses a spring 412 (Figs. 18 and 23) mounted between a cut-out portion in the plate 413 pinned to the feed gear hub 279 by a pin 414 to a pin mounted in the gear 278. The operator adds his pressure to the pressure of the motor 300 and the wheel slide assembly will be raised as the hand wheel is kept rotating by the pressure of the operator. The friction plate 280 will slip but maintain the lever 415 in the operating position. When the hand wheel is stopped, the released tension of the spring 413 and the pendulum action of the lever 415 will return it to its central or neutral position provided the friction does not slip. The spring 315 will also assist this movement of the lever 415, also obtained when the vane motor 380 lifts the grinding wheel 65 at the end of the cycle. In this case the motor 380 furnishes the additional power required.

A stud 430 is adjustably supported adjacent to the lower end of the lever 415. The stud 430 is positioned in the path of movement of a pair of adjustable collars 431 (Fig. 21) which are screw threaded onto a threaded sleeve carried by the valve stem 311. When the hand wheel 282 is rotated in a clockwise direction (Figs. 20 and 24) to raise the wheel slide 50, the lever 415 will be moved also in a clockwise direction and the stud 430 engaging the adjustable collars 431 will shift the valve stem 311 toward the left a sufficient distance to open a port in the valve 310 so as to admit fluid under pressure to the motor 300. The power of the motor 300 in this position of the valve, however, is slightly less than that required to rotate the feed screw 250. The operator supplies the necessary additional power on the hand wheel 280 to impart a rotary movement to the feed screw 250 to raise the grinding wheel assembly to the required extent. As soon as the rotary movement of the hand wheel 280 is stopped, the released compression of the spring 315 will shift the valve 310 back to its neutral or central position, thus cutting off the flow of fluid under pressure to the fluid motor 300. By continuing the rotary movement of the hand wheel 280, the grinding wheel 65 may be raised to the required extent.

If it is desired to lower the grinding wheel manually, the hand wheel 282 is rotated in a counterclockwise direction, which movement, through the friction plate 418, rocks the lever 415 so that its lower end engages the adjustable stop screw 428 (Fig. 18). This movement of the lever 415 does not shift the valve 311 and continued rotation of the hand wheel 282 through the gear mechanism previously described rotates the shaft 272 and this in turn through the gear mechanism previously described rotates the feed screw 250 to cause a lowering of the wheel slide 50 supporting the grinding wheel 65 to position the grinding wheel 65 manually as desired.

Cross feed—wheel slide

The transversely movable grinding wheel slide 50 is arranged so that it may be moved transversely by means of a manually operable traversing or feeding mechanism or, if desired, the grinding wheel slide may be fed transversely by an intermittently incremental movement actuated by and in timed relation with the work table reciprocation to advance the grinding wheel automatically at the ends of the reciprocatory stroke of the table. A further transverse movement is provided whereby the wheel slide 50 may be continuously moved transversely at a slow uniform rate during a grinding wheel truing operation.

Hand traverse

The wheel slide 50 is provided with a rack bar 435 which extends lengthwise of the wheel slide. A gear 436 meshes with the rack bar 435 and is fixedly mounted on the end of a rotatable shaft 437. The shaft 437 is journalled in anti-friction bearings 438 and 439 which are supported by the vertically movable slide 48.

A large bevel gear 440 is keyed to the shaft 437 (Fig. 33). A bevel gear or pinion 441 is mounted at one end of a rotatable shaft 442 which is journalled in anti-friction bearings 443 and 444. The bearings 443 and 444 are supported in a slidably mounted sleeve 445 which is journalled in a suitable aperture within the vertical slide 48 (Fig. 30). The sleeve 445 is slidably keyed by means of a key 446 to a bracket 454 fixedly mounted on the vertical slide 48, so that the sleeve 445 may be moved endwise but held against rotation. The sleeve 445 may be positioned (Fig. 30) with the bevel pinion 441 out of mesh with the bevel gear 440 during a power traversing movement of the wheel slide 50. In case it is desired to traverse the wheel slide 50 manually, the sleeve 445 is moved toward the left (Fig. 30) to move the bevel pinion 441 into mesh with the bevel gear 440. The shaft 442 carries a member 447 to which is fixedly mounted a manually operable hand wheel 448, the member 447 and the hand wheel 448 being arranged to rotate together. When it is desired to traverse the wheel slide 50 manually, the hand wheel 448 is moved into dotted line position 448a which moves the sleeve 445 and the bevel gear 441 also toward the left (Fig. 30) to mesh the bevel pinion 441 with the bevel gear 440. Rotary movement of the hand wheel 448 will then transmit a comparatively fast traverse to the grinding wheel slide 50.

In case it is desired to produce a relatively slow transverse movement of the grinding wheel slide 50 under manual control, a locking pin 449 is provided. The locking pin 449 (Figs. 30 and 32) is carried by the hand wheel 448 and member 447 and is arranged to engage any one of a series of notches 450 formed in the bracket 454 which is fixedly supported on the vertical

slide 48, thereby locking the hand wheel 448 against rotation.

A speed reducing unit 451 (Fig. 30) is fixedly mounted within an integral hub of the hand wheel 448. This speed reduction unit has not been shown in detail since this reduction unit is the well known "Heliocentric" speed reduction unit manufactured by Universal Gear Corporation of Indianapolis, Indiana. A hand wheel 452 is mounted on a drive shaft 453 of the speed reduction unit 451. When the hand wheel 448 is locked by the locking pin 449 against rotary movement and the hand wheel 452 is rotated, a relatively slow rotary movement is transmitted by the speed reduction unit 451 to move the wheel slide 50 transversely at a slow uniform truing speed. The diamond is held by the diamond holder which is adjustably mounted in a truing attachment unit 465 fixedly mounted on the vertical slide 48 (Figs. 1 and 2). Such a traversing movement is desirable in case it is desired to true the grinding wheel 65 manually.

Hydraulic traverse—Wheel slide

The wheel slide 50 is preferably moved transversely during the automatic grinding cycle and also during a truing operation by means of a hydraulically operated mechanism comprising a fluid pressure cylinder 455 which is fixedly mounted on the vertically movable slide 48 (Figs. 2 and 30). A piston 456 is slidably mounted within the cylinder 455 and is connected to the central portion of a double end piston rod 457. The rod 457 is connected by means of a bracket 458 to the wheel slide 50. The bracket 458 is either fixedly mounted on or formed integral with the wheel slide 50. Fluid under pressure from the pump 135 previously described passes through a pipe 459 (Fig. 3) to a pilot valve 460 and also to an automatic wheel slide traverse control valve 461, both valves being attached to a bracket 466 which is fixedly mounted to the vertical slide 48. A selector valve 462 is provided for controlling the hydraulic operation of the wheel slide 50. The selector valve 462 is a rotary type valve controlled by a manually operable dial 463 which is mounted adjacent to the front of the vertical slide 48. The dial 463 may be rotated to any one of three positions. An index point 464 is provided to facilitate location of the dial 463 in the desired operating position. As illustrated in Fig. 33, the dial 463 and valve 462 are set for an intermittent incremental cross feeding movement of the grinding wheel 65 at the ends of the reciprocatory stroke of the work table 41. If it is desired to traverse the wheel slide 50 by hand, the dial 463 is rotated in a clockwise direction (Fig. 33) until the word "Hand" is opposite the index pointer 464. Similarly, if it is desired to true the grinding wheel 65, the dial 463 is rotated (Fig. 33) in a clockwise direction until the word "True" is opposite the index pointer 464.

The valve 462 (Fig. 3) has been shown diagrammatically in the three operating positions, only one of which is connected in full lines with the main piping of the machine. The selector valve 462 (Fig. 3) is connected in full lines with the piping diagram, and is shown in position for an automatic incremental cross feeding movement in timed relation with the reciprocatory movement of the work table 41. The selector valve 462 is also shown in position 462*a* (Fig. 3), in which position the valve is positioned so that fluid may by-pass from one end of the cylinder 455 to the other end thereof to allow free unrestrained movement of the wheel slide 50 under the influence of the manually operable traverse hand wheels 448 and 452, respectively. The valve 462 is also shown in position 462*b* (Fig. 3) which is in a truing position to be hereinafter described.

For fine adjustments of the speed and amount for cross feeding, a screw 485 is threaded in the bracket 466 which positions the dial 463. The dial 463 has an integral abutment on the projection 486 (Figs. 3 and 33) which strikes the screw 485, thereby locating the valve stem 507 of the selector valve 462 in the desired relationship with the V-ports (Figs. 38 and 40). The V-ports are connected with the exhaust pipe 515 leading to the valve 517, in this way controlling the amount the grinding wheel 65 may be fed for the next grinding pass. An adjusting screw 487 positions the projection 486 of the dial 463 which in turn positions the valve stem 507 (Fig. 38) for a desired truing speed of the grinding wheel 65 across the truing unit 465. The shape of the truing exhaust ports in the sleeve of the selector valve 462 is shown in Fig. 38.

The reversing valve 461 is a piston type reversing valve comprising a valve stem 473 having formed integrally therewith a plurality of valve pistons. The reversing valve 461 serves to admit fluid under pressure either through a pipe 474 or a pipe 475 into cylinder chambers 476 or 477 of the cylinder 455 to produce a longitudinal movement of the piston 456 and the wheel slide 50.

The valve stem 473 is provided with a cam 478 at its right-hand end (Fig. 3). When the valve stem 473 together with the cam 478 is moved toward the right (Fig. 3), the cam 478 serves to open a normally closed limit switch 479 and simultaneously to close a normally open limit switch 480 mounted on the bracket 466. During the movement of the valve stem 473 toward the right (Fig. 3), a pivotally mounted detent 481 carried by the valve stem 473 rides idly over the actuating plunger of a normally open limit switch 482. When the valve is moved toward the left (Fig. 3), the detent 481 actuates the plunger and closes the limit switch 482. The limit switches 479, 480 and 482 are electrically interconnected with the other mechanisms of the machine in a manner to be hereinafter described.

An automatic reversing mechanism is provided for shifting the pilot valve stem 468. The shaft 437 is provided with a reduced extension 488 which supports at its right-hand end (Fig. 33) a spiral gear 489 which meshes with a spiral gear 490 (Figs. 33 and 34). The spiral gear 490 is mounted on the right-hand end of a shaft 491 (Fig. 34) which is journalled in bearings 492 and 493, respectively, which are in turn supported in the bracket 466 mounted on the vertically movable slide 48. A reversing plate 494 is mounted on the left-hand end of the shaft 491 (Fig. 34). The plate 494 is provided with a T-shaped annular groove 495 extending around the plate 494 adjacent to its periphery. A pair of reversing dogs 496 and 497 are adjustably supported by means of the T-slot 495. A graduated dial scale 498 is provided to facilitate positioning of the reversing dogs 496 and 497. For convenience in this positioning movement, the graduations of the scale 498, as illustrated, are in inches per distance of cross traverse of the grinding wheel 65.

A reversing lever 500 (Figs. 36 and 37) is pivotally mounted on a stud 501 which is fixedly mounted in the bracket 466 supported on the vertical slide 48. The lever 500 is provided at its

lower end with a stud 502 which engages the groove in the spool-shaped member 469. As the wheel slide 50 is traversed first in one direction and then in the other intermittently by incremental steps during a grinding operation, the reversing plate 494 is similarly rotated first in one direction and then reversed and rotated in the opposite direction by the reversing mechanism above described. When one of the reversing dogs, for example dog 496 (Fig. 37), engages an arrow-pointed spring-pressed detent 503, the reversing lever 500 will be rocked on its supporting stud 501 to shift the pilot valve 460, thereby to shift the reversing valve 461 and change the direction of movement of the wheel slide 50.

During the automatic traverse of the wheel slide 50 by fluid under pressure, it is desirable to maintain the manually operable traverse mechanism in an inoperative position with the parts as illustrated in Fig. 30, namely with the bevel pinion 441 out of mesh with the bevel gear 440. In order to prevent engagement of the hand traverse mechanism, the sleeve 445 is provided with a stud 505 which projects into the path of a collar 506 carried by a valve stem 507 of the selector valve 462. The collar 506 is provided with a longitudinally extending groove 508.

When it is desired to traverse the wheel slide 50 by hand, the dial 463 is rotated in a clockwise direction. When the dial 463 is positioned in a hand traversing position, that is, when the word "Hand" is opposite the index pointer 464, the groove 508 shifts into position 508*a* (Fig. 36) so that it is aligned with the end of the stud 505. In this position of the parts, the hand wheel 448 may be readily shifted to engage the bevel pinion 441 with the bevel gear 440, thus facilitating a manual traverse of the wheel slide 50.

During the hand traverse operation it is desirable that the automatic reversing mechanism be rendered inoperative in case it is desired to traverse the wheel slide 50 beyond the normal stroke for which the machine is set. To facilitate such a movement of the lever 500, it is slidably supported on the stud 501 and during the hydraulic traverse of the wheel slide 50 is held in the position illustrated in Fig. 36 by means of a cam 509 carried by the valve stem 507. A spring 510 serves to maintain the lever 500 with a follower stud 511 in engagement with the cam 509. When the dial 463 is turned to a manual traverse of the wheel slide 50, the cam 509 is also rotated in a clockwise direction so that the follower stud 511 rides down to a position 511*a*, which movement releases the tension of the spring 510 to shift the reversing lever 500 into position 500*a* (Fig. 36), thus shifting the spring-pressed detent 503 out of the path of the reversing dogs 496 and 497 so that the wheel slide 50 may be traversed to any desired extent without disturbing the setting of the reversing dogs 496 and 497.

Fluid exhausting from either end of the cylinder 455 passes through one of the chambers in the wheel slide reversing valve 461 and passes out through the selector control valve 462 and through a pipe 515 and a traverse valve 517 mounted on the vertical slide 48 (Figs. 2 and 27) and which is actuated by a push type solenoid 518. In the position of the parts (Fig. 3), fluid under pressure passing through the pipe 515, the valve 517, and through a pipe 519, exhausts into the reservoir 125, thus allowing exhaust of fluid at a controlled rate of speed. An adjustable relief valve 516 connected to a pipe 514 allows fluid to exhaust from the cylinder 455 through the pipe 515 when the solenoid 518 is released. This serves to close the valve 517 to prevent vibrating the wheel slide 50 when it is suddenly stopped. The rapid cross feed of the grinding wheel 65 is obtained by energizing the solenoid 518 to open the valve 517 so as to allow unrestricted passage of fluid from the pipe 515 through the valve 517 and the pipe 519 into the reservoir 125. The duration of the period within which the solenoid 518 is energized determines the extent of cross feed of the wheel slide 50.

When it is desired to true the grinding wheel 65, it is desirable to provide a slow uniform continuous traverse of the wheel slide 50. This is preferably accomplished by energizing the solenoid 518 and holding it energized during the entire truing operation. This is preferably accomplished by providing a cam 520 fastened on the rear end of the valve stem 507 which is arranged to actuate a normally open limit switch 521 (Figs. 3, 30 and 39). When the dial 463 is rotated to a truing position, the cam 520 closes the limit switch 521 which in turn actuates a normally open electrical relay or contactor 522 to close a circuit and maintain the solenoid 518 in an energized position during the truing operation.

Operation

The operation of the improved surface grinding machine will be readily apparent from the foregoing disclosure, assuming all of the adjustments of the various mechanisms to have been previously made and the machine to be set up for grinding a predetermined work piece to the required extent. A selector switch 525 is positioned for an automatic cycle. A switch 526 is closed to start the pump drive motor 527. A push button 528 is actuated to start the wheel drive motor 68.

A work piece 529 is then positioned on the work table 41 when the table 41 is in its extreme left-hand position (Fig. 1). The start and stop lever 215 is then shifted in a clockwise direction (Fig. 8) into position 215*a* to move the start and stop valve 205. The shifting of the start and stop valve 205 toward the left (Fig. 3) serves to allow fluid to exhaust from cylinder chamber 114 in cylinder 100 and thereby allow the pressure passing through pipe 111 into the cylinder chamber 112 to start the table 41 traversing toward the right (Fig. 1).

When the start and stop valve stem 206 is moved toward the left to start a grinding cycle, the cam 229 (Fig. 3) closes the normally open limit switch 230 which serves to render the electrical cycle timer or counter 231 operative and at the same time energizes the solenoid 187 which produces a downward movement of the roller 148 to shift it downwardly to position 148*a* (Fig. 4) into the path of the cam 162 on the table dog 163. At the same time the solenoid 187 is energized, a normally open electrical relay 530 (Fig. 3) is energized to close a circuit connected with the normally open switch 531 (Figs. 4 and 12). The traverse of the table 41 toward the right continues until the roller 147 engages the cam 156 on the table dog 157, and continued movement of the table 41 serves through the shaft 149 and lever 165 to start a reverse movement of the reversing valve 110. During the shifting movement of the reverse valve a cam 532 carried by the rod 167 closes the normally open limit switch 531. The limit switch 531 operates through the relay 530 and the limit switch 479 to actuate the relay 522. The closing of the relay 522 serves to

energize the solenoid 518 which shifts the valve 517 upwardly to allow exhaust of fluid from the wheel slide cylinder chamber 477 and pipe 475, thereby permitting the fluid under pressure from passing through the pipe 474 into the cylinder chamber 476 to move the piston 456 toward the right (Fig. 3) so as to feed the wheel slide 50 and the grinding wheel 65 toward the right (Fig. 2) so that on the next traverse of the work table 41, the grinding wheel 65 will grind a fresh path across the face of the work piece 529. The solenoid 518 is only energized instantaneously while the cam 532 passes over the plunger of the limit switch 531, after which the solenoid 518 is deenergized and the valve 517 moved downwardly to stop the cross feeding movement of the grinding wheel 65. The reversing valve 110 completes its reversal by the influence of fluid under pressure in a manner similar to that described in the prior U. S. patent to W. H. Wood, No. 2,071,677 dated February 23, 1937. The cycle just described is continued until the grinding wheel 65 has successively ground paths across the entire face of the work piece 529.

During the cross feeding movement of the grinding wheel 65 and its supporting wheel slide 50, the reversing plate 494 moves intermittently in a counterclockwise direction (Fig. 3) until the dog 497 engages the detent 503 to rock the reversing lever 500 in a counterclockwise direction (Figs. 34 and 37), which movement shifts the pilot valve 460 toward the right (Fig. 3) to admit fluid under pressure from the pipe 459 through the pipe 472 to shift the wheel slide reversing valve 461 toward the right (Fig. 3) to reverse the direction of movement of fluid to and from the cylinder 455.

During the shifting movement of the wheel slide reversing valve 461 toward the right, the cam 478 carried by the valve stem 473 closes the limit switch 480 which serves to close a circuit and energize the solenoid 534 to shift the valve 535 (Fig. 12) upwardly. The upward movement of the valve 535 admits fluid under pressure from the pipe 536 through the pipe 353 into the cylinder chamber 354 to shift the piston 349, piston rod 348 and link 346 toward the left (Fig. 19) to rock the lever 344 which, through the mechanism previously described, swings the stud 331 together with the feed arm 330 in a downward arcuate path to rotate the feed gear 280 which in turn transmits a rotary movement to the feed screw 250 automatically to feed the vertical slide 48 downwardly so that the grinding wheel 65 assumes a new position for the next pass of the grinding wheel across the operative face of the work piece 529. The table 41 continues its reciprocatory movement and the grinding wheel 65 is traversed transversely toward the left (Fig. 2) by intermittent successive increments until the grinding wheel 65 again reaches the position illustrated in Fig. 2, thus completing the second pass of the grinding wheel 65 across the face of the work piece 529 being ground.

During this movement of the wheel slide 50 and grinding wheel 65 toward the left, the reversing plate 494 moves in a clockwise direction (Fig. 33) until the dog 496 engages the detent 503 to rock the reversing lever 500 in a clockwise direction (Fig. 37) to again shift the pilot valve 460 into the position shown in Fig. 3. This movement of the pilot valve 460 reverses the direction of flow of fluid so that fluid passes through the pipe 471 to move the reversing valve 461 toward the left into the position illustrated in Fig. 3. During the movement of the reversing valve 461 toward the left, the detent 481 engages and closes the limit switch 482 which is connected to the time cycle counter 231 to give the timer an impulse.

After a predetermined number of complete reciprocations of the grinding wheel 65 across the face of the work piece 529 which is being ground during the continuous reciprocation of the work table 41 a corresponding number of impulses is imparted to the cycle counter 231, after which the counter 231 deenergizes the solenoid 187 and the relay 530 to release the tension of the spring 193, thus shifting the roller 148 upwardly out of the path of the cam 162 on the dog 163, so that the table 41 will travel to its extreme left-hand or loading position. In this position of the roller 148, the roller engages a cam 160 on the dog 161 which rocks the reversing lever 146 a sufficient distance to shift the table reversing valve 110 so as to have the table ready to go to the left (Fig. 1) for the start of the next cycle, thus ending one complete grinding cycle. At the same time, the dog 161 rocks the control lever 215 (Fig. 8) into the position 215*a*, thereby shifting the stop and start valve 205 to stop the table 41 in a loading position. The time cycle counter 231 may be set as desired so that, depending upon the amount of stock desired to be removed from the work piece 529, the grinding wheel 65 may be fed downwardly and traversed intermittently by successive increments across the work face a predetermined number of times, after which the machine automatically stops without attention on the part of the operator.

Shifting of the stop and start valve 205 into the position shown in Fig. 3 opens a port to admit fluid under pressure through the pipe 382 into the fluid motor chamber 383 to cause the vane 381 of the motor 380 to rotate in a counterclockwise direction. This movement serves through the gears 390 and 391 to rotate the gear 277 to transmit a rotary movement through the mechanism previously described to rotate the vertical feed screw 250 in the reverse direction automatically to return the grinding wheel 65 into its initial position so that it is ready for the next grinding cycle. At the start of the grinding cycle when the stop and start valve 205 is shifted toward the left (Fig. 3), the fluid within the fluid vane motor chamber 383 is opened to the exhaust, thus releasing the tension of the spring 386 which rotates the vane 381 in a clockwise direction (Fig. 3) to reset the motor 380 ready for the end of the next cycle.

If for any reason it is desired to control the cycle of operation manually instead of automatically, the selector switch 525 is shifted to a hand position, in which position the table 41 may be reciprocated under manual control and the wheel slide 50 may be traversed also under the manual control of the operator.

When the selector switch 525 is turned to a "Hand" position, the cycle-timing counter 531 is rendered inoperative. The relay 530 is energized and the solenoid 187 deenergized so that the wheel slide 50 is automatically fed across the work by means of the cam 532 closing the limit switch 531. When the machine is under "Hand" control, the grinding cycle may be stopped by unlocking the stud 198 in the slot 200 and lifting the stud 198 to raise the roller 148 out of the path of the cam 162 on the dog 163 so as to allow the table 41 to move to its left-hand or loading position.

It will thus be seen that there has been provided by this invention apparatus in which the various objects hereinabove set forth together with many thoroughly practical advantages are successfully achieved. As many possible embodiments may be made of the above invention and as many changes might be made in the embodiment above set forth, it is to be understood that all matter hereinbefore set forth or shown in the accompanying drawings is to be interpreted as illustrative and not in a limiting sense.

I claim:

1. In a surface grinding machine having a base, a longitudinally reciprocable table thereon, a vertically movable slide, a transversely movable slide on said vertical slide, a rotatable grinding wheel on said transversely movable slide, means automatically to reciprocate said table, means intermittently to feed or index the wheel slide transversely at the end of a reciprocatory stroke of the table, means actuated in timed relation with the transverse indexing movement of the wheel slide automatically to feed the vertical slide downwardly after each cross traverse of the wheel slide, and an electrically actuated cycle control mechanism automatically to stop the grinding operation after a work piece has been ground to the desired extent.

2. In a surface grinding machine having a base, a longitudinally reciprocable table thereon, a vertically movable slide, a transversely movable slide on said vertical slide, a rotatable grinding wheel on said transversely movable slide, means including a fluid motor automatically to reciprocate said table, means including a fluid motor intermittently and automatically to feed or index the wheel slide transversely at the end of the table stroke, and means including a fluid motor actuated in timed relation with the transverse indexing movement of the wheel slide automatically to feed the vertical slide downwardly after each cross traverse of the wheel slide.

3. In a surface grinding machine having a base, a longitudinally reciprocable table thereon, a vertically movable slide, a transversely movable slide on said vertical slide, a rotatable grinding wheel on said transversely movable slide, means including a fluid motor to reciprocate said table, means including a fluid motor intermittently to feed or index the wheel slide transversely, means including a fluid motor actuated pawl and ratchet feed mechanism automatically to feed the vertical slide downwardly after each cross traverse of the wheel slide, means including an electrically operated time relay mechanism to stop the grinding operation after the grinding has proceeded to a predetermined extent.

4. In a surface grinding machine having a base, a longitudinally reciprocable work supporting table thereon, a vertically movable slide, a transversely movable slide on said vertical slide, a rotatable grinding wheel on said transversely movable slide, means automatically to reciprocate said table, means intermittently to feed or index the wheel slide transversely at the ends of the table stroke, means automatically to feed the vertical slide downwardly after each cross traverse of the wheel slide, means automatically to stop the grinding operation after a work piece has been ground to the desired extent, and means automatically to raise the vertical slide to its initial position for the next operation.

5. In a surface grinding machine having a base, a longitudinally reciprocable work supporting table, a vertically movable slide, a transversely movable slide on said vertical slide, a rotatable grinding wheel on said transversely movable slide, means automatically to reciprocate said table, means intermittently to feed or index the wheel slide transversely at the end of the table stroke, means automatically to feed the vertical slide downwardly after each cross traverse of the slide, means automatically to stop the grinding operation, and means including a fluid motor which is operatively connected to raise said vertical slide to its initial position for the next grinding operation.

6. In a surface grinding machine having a base, a longitudinally reciprocable work supporting table thereon, a vertically movable slide, a transversely movable slide on said vertical slide, a rotatable grinding wheel on said transversely movable slide, means including a fluid motor to reciprocate said table, means including a fluid motor intermittently to feed or index the wheel slide transversely, means including a fluid motor actuated pawl and ratchet mechanism automatically to feed the vertical slide downwardly after each cross traverse of the wheel slide, and means including a fluid motor automatically actuated to raise said vertical slide to return the grinding wheel to its initial position after the grinding operation has proceeded to a predetermined extent.

7. In a grinding machine as claimed in claim 2, the combination with the parts and features therein specified, of a rotary type fluid motor, a tumbler gear mechanism actuated thereby which is arranged automatically to engage said tumbler gear to raise the vertical slide to return the grinding wheel to its initial position after a predetermined grinding operation.

8. In a grinding machine as claimed in claim 2, the combination with the parts and features therein specified, of a nut and feed screw mechanism to raise and lower the vertical slide, means including a fluid motor, and a tumbler gear mechanism which is actuated automatically by said motor to engage the tumbler gear so as to rotate said screw to move the vertical slide upwardly to return the grinding wheel to its initial position after a predetermined grinding operation.

9. In a grinding machine as claimed in claim 2, the combination with the parts and features therein specified, of a nut and screw mechanism to raise and lower the vertical slide, a single vane type fluid motor, means including an automatically actuated tumbler gear mechanism which is actuated by and driven by said motor to rotate said screw so as to raise the vertical slide to its initial position after a predetermined grinding operation.

10. In a surface grinding machine having a base, a longitudinally reciprocable table thereon, a vertically movable slide, a transversely movable slide on said vertical slide, a rotatable grinding wheel on said transversely movable slide, means including a fluid motor automatically to reciprocate said table, means including a fluid motor independently to index the wheel slide transversely, means including a fluid pressure actuated pawl and ratchet feed mechanism automatically to feed the vertical slide downwardly after each cross traverse of the wheel slide, a manually operable start and stop valve which is operatively connected to start a grinding cycle, and an electrically operated impulse type count-

ing relay which is rendered operative when the stop and start valve is moved to initiate a grinding cycle, and electrically actuated means controlled by said counting relay automatically to traverse said table beyond its normal grinding stroke after a predetermined grinding operation has been completed.

11. In a surface grinding machine having a base, a longitudinally reciprocable table thereon, a vertically movable slide, a transversely movable slide on said vertical slide, a rotatable grinding wheel on said transversely movable slide, means including a fluid motor to reciprocate said table, means including a fluid motor intermittently to feed or index the wheel slide transversely, means including a fluid pressure actuated pawl and ratchet feed mechanism automatically to feed the vertical slide downwardly after each cross traverse of the wheel slide, means including a stop and start valve to initiate a grinding cycle, an electrical impulse counting relay which is rendered operative by movement of said valve to a start position, means controlled by said counter to shift said valve to a stop position, and a fluid motor rendered operative when the valve shifts to a stop position to raise the vertical slide to its initial grinding position.

12. In a surface grinding machine having a base, a longitudinally reciprocable table thereon, a vertically movable slide, a transversely movable wheel slide on said vertical slide, a rotatable grinding wheel thereon, means including a fluid motor automatically to reciprocate said table, means including a fluid motor intermittently to index the wheel slide transversely, a reversing valve which is automatically actuated to reverse the direction of indexing movement of the wheel slide after it has been indexed to a predetermined distance, an electrical impulse relay to control the duration of the grinding cycle, an electric switch which is actuated by the wheel slide reversing valve to impart an impulse to said counter after each complete transverse movement of the wheel slide, and means actuated automatically after a predetermined number of impulses to stop the grinding cycle.

13. In a grinding machine having a base, a longitudinally reciprocable table, a fluid pressure system including a piston and cylinder operatively connected to reciprocate said table, a reversing valve therefor, a stop and start valve to control the stopping and starting of the table reciprocation, a manually operable lever to actuate the stop and start valve, means including a rock arm having a pair of spaced rollers which are arranged to actuate said reversing valve, adjustable dogs on said table having cam surfaces arranged to engage said rollers to shift the reversing valve so as to change the direction of movement of the table, an electrical solenoid operatively connected to hold one of said rollers in the path of its table dog during grinding, a spring to move said roller out of the path of its dog when the solenoid is deenergized to allow the table to traverse beyond its normal grinding stroke into a loading position, and an electrical impulse relay operatively connected to deenergize said solenoid after a predetermined grinding operation.

14. In a grinding machine having a base, a longitudinally reciprocable table, a fluid pressure system including a piston and cylinder to reciprocate said table, a reversing valve therefor, a rotatable grinding wheel, a transversely movable slide for said grinding wheel, means including a piston and cylinder to index said slide transversely, a reversing mechanism to control the direction of movement of said wheel slide, a stop and start valve to control the stopping and starting of the wheel slide indexing movement, and an electrically operated control mechanism including a switch and an electrical impulse relay which is actuated by the table reversing valve to actuate said stop and start valve to index the grinding wheel slide transversely during table reversal.

15. In a grinding machine having a base, a longitudinally reciprocable table, a fluid pressure system including a piston and cylinder to reciprocate said table, a reversing valve therefor, a rotatable grinding wheel, a transversely movable slide for said wheel, means including a piston and cylinder to index said slide transversely, a reversing valve to control the direction of movement of said slide, a solenoid-actuated normally-closed valve to control the exhaust of fluid from the wheel slide cylinder, and an electrically operated mechanism including a switch and an electrical impulse relay actuated by said table reversing valve whereby the solenoid valve is opened and the wheel slide indexed transversely during table reversal.

16. In a grinding machine having a base, a longitudinally reciprocable table, a fluid pressure system including a piston and cylinder to reciprocate said table, a table actuated reversing valve therefor, a rotatable grinding wheel, a transversely movable wheel slide for said wheel, means including a piston and cylinder to index said wheel slide transversely, a solenoid-actuated normally-closed valve to control the exhaust of fluid from the wheel slide cylinder so as to control the movement thereof, a cam movable with the table reversing valve, a normally open limit switch actuated by said cam, and electrical connections between said switch and solenoid valve whereby the wheel slide is indexed transversely during table reversal.

17. In a grinding machine having a base, a longitudinally reciprocable table, a fluid pressure system including a piston and cylinder to reciprocate said table, a reversing valve therefor, a manually operable stop and start valve, a rotatable grinding wheel, a transversely movable slide therefor, a piston and cylinder to move said slide, a reversing valve therefor, a solenoid actuated valve to control said wheel slide movement, and an electrical control system including a normally open switch which is closed by the shifting of the table reverse valve, a relay switch actuated thereby to close a circuit and open said solenoid valve instantaneously during each shifting movement of the table reversing valve to index the wheel slide transversely during each table reversal.

18. In a grinding machine having a base, a longitudinally reciprocable table, a fluid pressure system including a piston and cylinder to reciprocate said table, a reversing valve therefor, a manually operable stop and start valve, a rotatable grinding wheel, a transversely movable slide therefor, a piston and cylinder to move said slide transversely, a reversing valve therefor, a solenoid actuated valve to control the flow of fluid from said wheel slide cylinder, and an electrical control system including a normally open switch, a cam which is movable with the table reversing valve to close said switch each time said valve

is shifted, a relay switch actuated thereby to close a circuit so as to open the solenoid valve instantaneously during each shifting movement of the table reversing valve to index the wheel slide transversely during each table reversal.

19. In a surface grinding machine having a base, a longitudinally reciprocable table thereon, a vertically movable slide, a transversely movable slide on said vertical slide, a rotatable grinding wheel on said transversely movable slide, means to reciprocate said table, means to feed or index the wheel slide transversely, a manually operable feed mechanism including a hand wheel to move said vertical slide, means including a pawl and ratchet mechanism automatically to actuate said feed mechanism to move the vertical slide downwardly after each cross traverse of the wheel slide, and means automatically to move said pawl out of engagement with the rachet at the end of its idle stroke to facilitate manual adjustment of the feed mechanism.

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