

2,979,870

GRINDING MACHINE

Filed April 22, 1958

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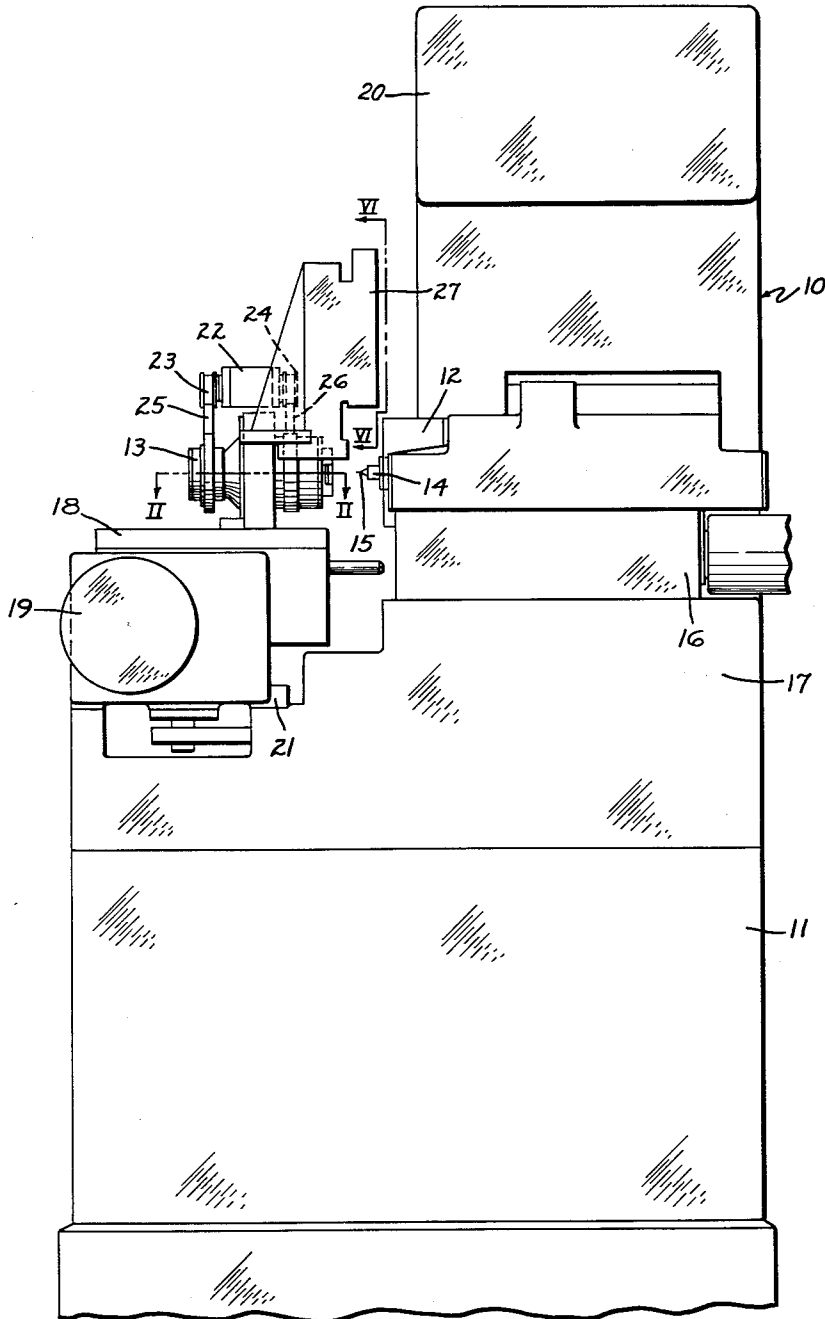


Fig. 1

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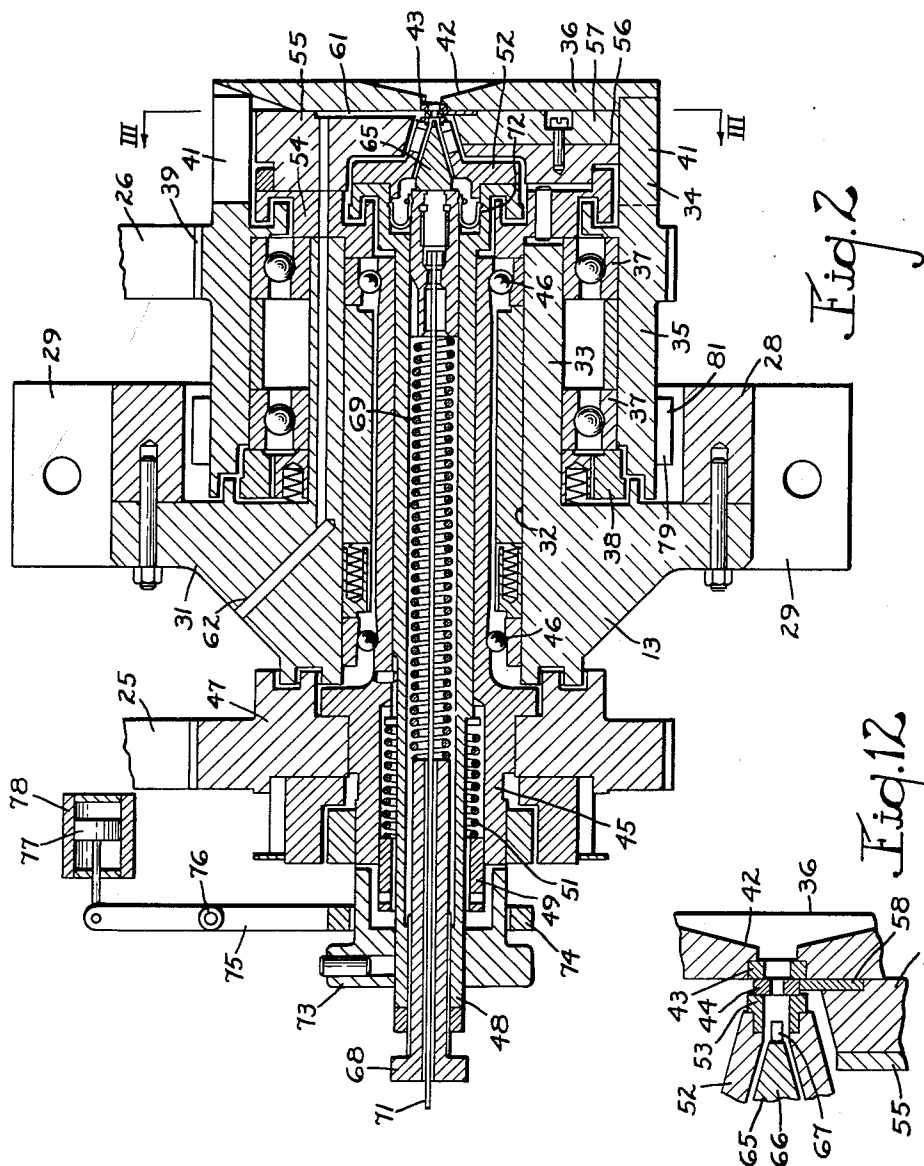
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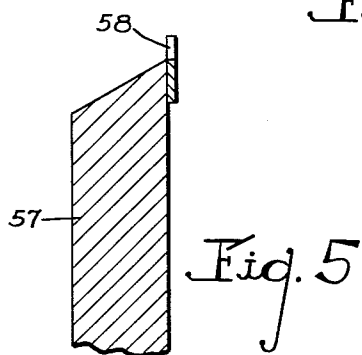
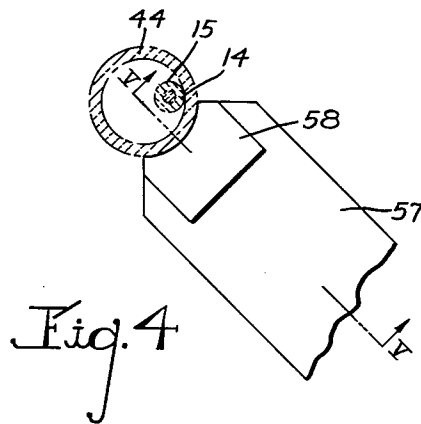
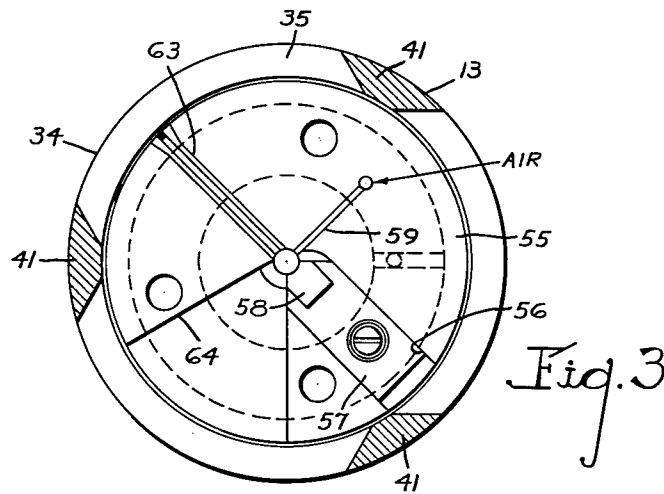
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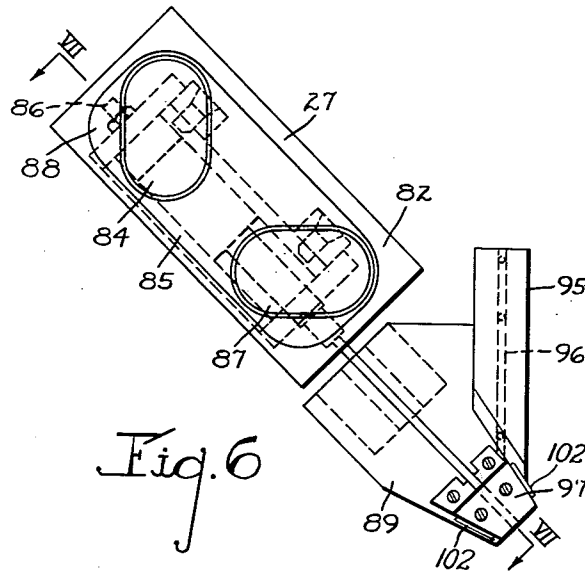


Fig. 6

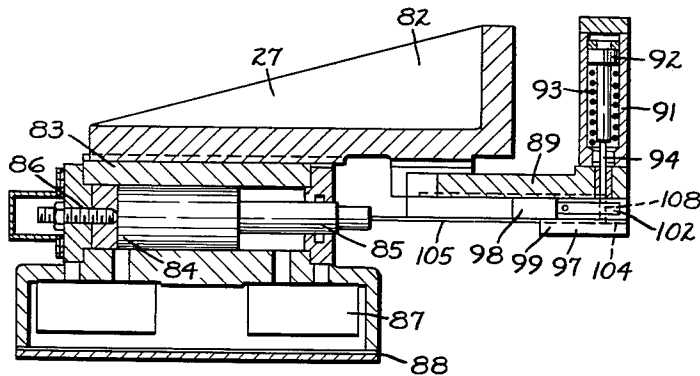


Fig. 7

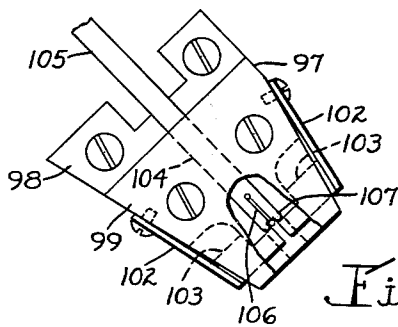


Fig. 8

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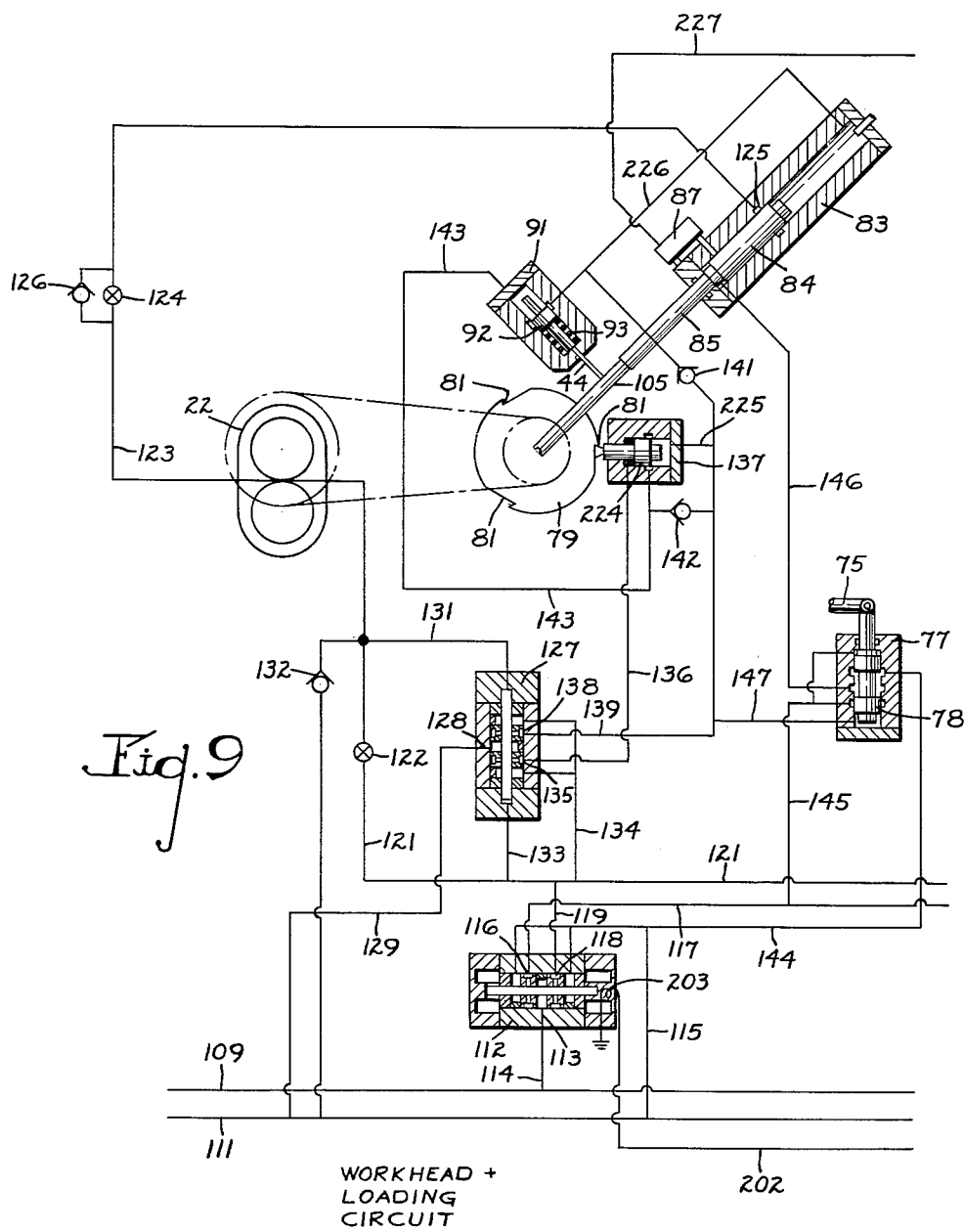
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GRINDING MACHINE

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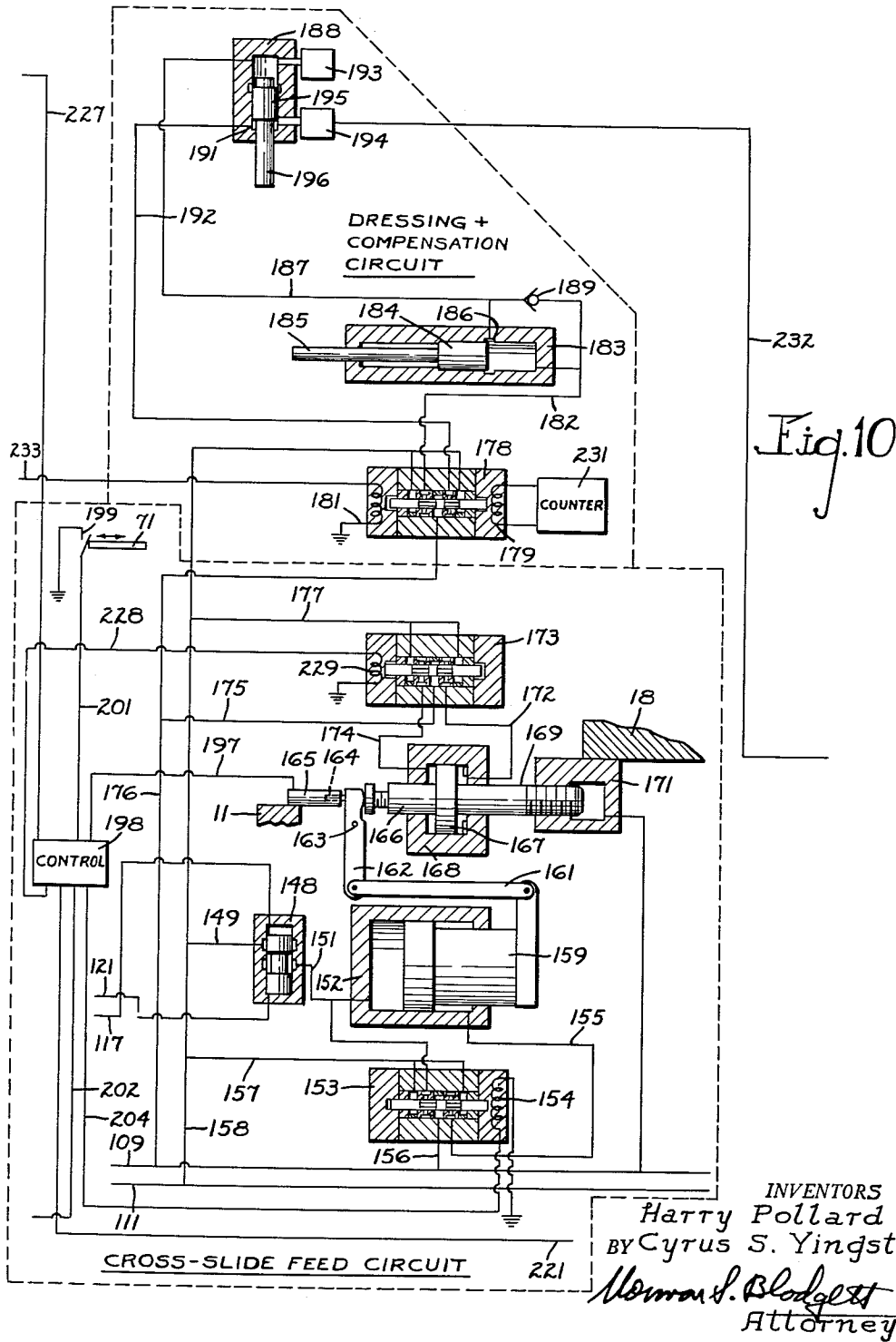
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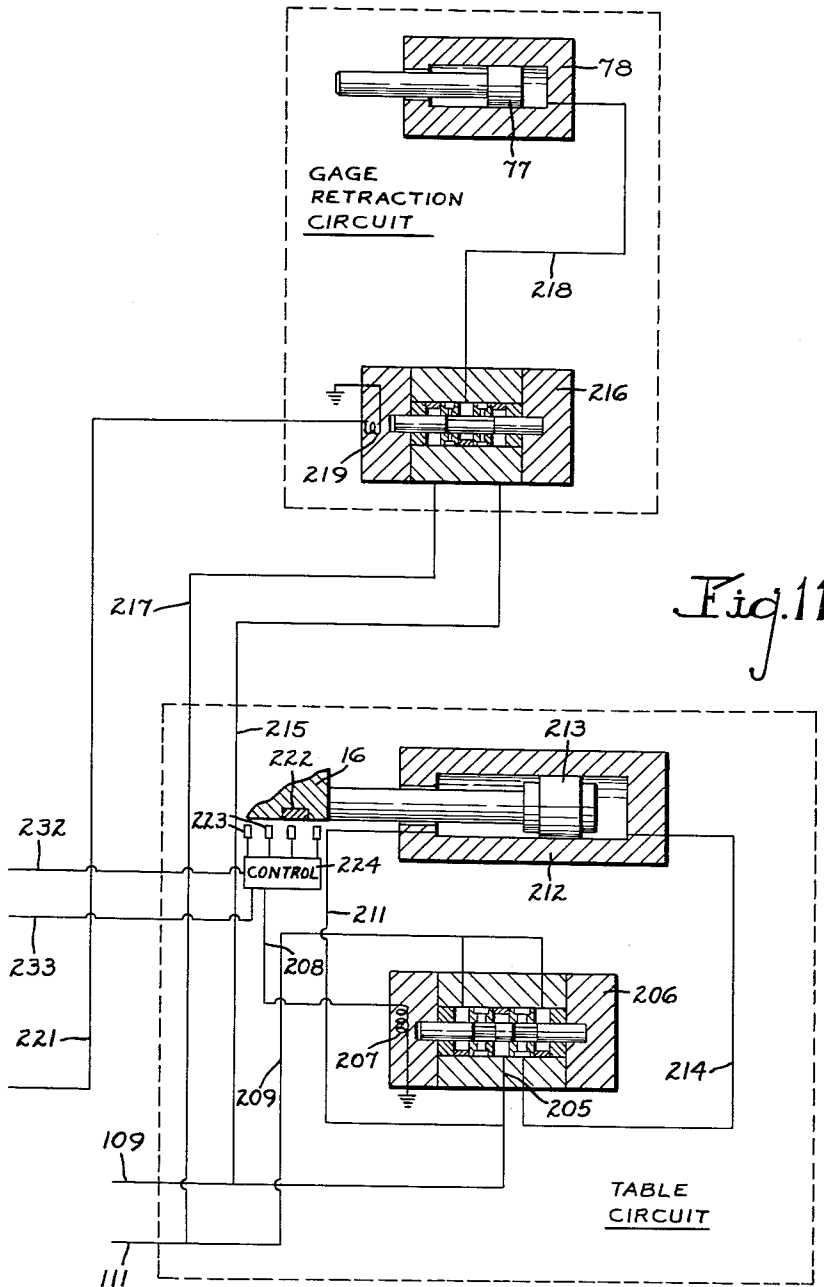


Fig. 11

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2,979,870

GRINDING MACHINE

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Filed Apr. 22, 1958, Ser. No. 730,213

8 Claims. (Cl. 51-215)

This invention relates to a grinding machine and more particularly to apparatus arranged to finish by abrasive action an internal surface of rotation of very small size.

The process of internal grinding of surfaces of revolution has been very well developed through the years. Generally speaking, the workpiece is rotated at a slow speed about the axis of the surface to be finished and a small abrasive wheel rotating at very high speed is moved into contact with the surface; while the abrasive wheel is being fed into the surface of revolution, the wheel is reciprocated along its axis. Attempts to apply this method of finishing to the bores of very small workpieces have not been altogether successful in the past. Principally, it has been found that the handling of very small workpieces, such as the races of miniature ball bearings, is very difficult. Since in the case of small workpieces the amount of material to be removed is small, it can be seen that the grinding cycle can be very short. Nevertheless, the devices for handling the workpieces, particularly during the loading and unloading portions of the cycle, have been unwieldy and have consumed portions of the overall grinding cycle out of proportion to the amount of work being done on the workpiece. These and other difficulties experienced with the prior art apparatus have been obviated in a novel manner by the present invention.

It is therefore an outstanding object of the invention to provide a grinding machine particularly adapted to the finishing by abrasion of internal surfaces of revolution in very small workpieces.

Another object of the instant invention is the provision of a machine tool having apparatus for rapidly loading and unloading small workpieces.

A still further object of this invention is the provision of a machine for finishing workpieces having control means to assure the operation of various elements of a finishing and handling system in proper sequence.

A further object of the invention is the provision of a grinding machine having a hydraulic system particularly adapted to rapid loading and unloading and to performing a grinding operation on a very small workpiece.

Another object of the present invention is the provision of a grinding machine having a workhead of unusual construction particularly adapted for use with very small workpieces.

With these and other objects in view, as will be apparent to those skilled in the art, the invention resides in the combination of parts set forth in the specification and covered by the claims appended hereto.

The character of the invention, however, may be best understood by reference to certain of its structural forms, as illustrated by the accompanying drawings in which:

Figure 1 is a front view of a grinding machine embodying the principles of the present invention,

Figure 2 is a horizontal sectional view of a portion of the invention taken on the line II-II of Figure 1,

Figure 3 is a vertical sectional view of a portion of the invention taken on the line III-III of Figure 2,

Figure 4 is an enlargement of a portion of the apparatus shown in Figure 3,

Figure 5 is a sectional view of the apparatus shown in Figure 4 taken on the line V-V of Figure 4,

Figure 6 is an elevational view of a portion of the apparatus, the view being taken on the line VI-VI of Figure 1,

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Figure 7 is a sectional view of the apparatus shown in Figure 6 taken on the line VII-VII thereof,

Figure 8 is an enlargement of a portion of the apparatus shown in Figure 6,

Figures 9, 10, and 11 are schematic views of hydraulic and electrical control apparatus associated with the machine, and

Figure 12 is an enlarged sectional view of a portion of Figure 2.

In the specification which follows the expression "longitudinal," "transverse," and the like refer to these same directions as related to the axis of the abrasive wheel used in the machine.

Referring first to Figure 1, wherein are best shown the general features of the invention, the grinding machine, indicated generally by the reference numeral 10, is shown as comprising a base 11 on which are mounted a wheelhead 12 and a workhead 13. On the back of the base 11 is mounted a control box 20 which contains many of the hydraulic and electrical elements for controlling the operation of the machine. The wheelhead 12 is provided in the usual manner with a spindle 14 on which is mounted a very small abrasive wheel 15. The shaft 14 and the wheel 15 are usually constructed integrally and are especially adapted for use in very small bores. The wheelhead 12 is so constructed as to be able to rotate the spindle 14 and the wheel 15 at a very high speed, in the order of 150,000-200,000 r.p.m.; this is necessary to maintain the optimum surface speed for abrasive grinding.

The wheelhead 12 is mounted on a table 16 which, in turn, is mounted on a raised portion 17 of the base 11; the table 16 is mounted on the portion 17 for sliding motion longitudinally of the wheel axis and is capable only of such longitudinal motion relative thereto. The workhead 13 is mounted on the upper surface of a cross slide 18 which is mounted on the base 11 for transverse sliding motion relative thereto. A feed mechanism 19 of the usual type is provided to bring about this transverse motion. The feed mechanism 19 is bolted to the top of the base 11 and the cross slide 18 moves relative to this base under the impetus of the feed mechanism 19.

Mounted on the workhead 13 is a jack shaft 22 on the ends of which are mounted pulleys 23 and 24 connected, respectively, by belts 25 and 26 to the main part of the workhead 13, as will be described more fully hereinafter. Also mounted on the workhead 13 is a loading mechanism 27.

Referring now to Figure 2, which represents a horizontal sectional view through the workhead 13, it can be seen that a mounting ring 28 is provided having feet 29 for bolting it to the upper portion of the cross slide 18. Fastened to the mounting ring is a main body 31 having a bore 32 extending therethrough and having a tubular extension 33. Mounted on the outside of the extension 33 is a workpiece clamp 34 having a tubular element 35 and a transverse plate element 36. Interposed between the inside surface of the tubular element 35 and the outside surface of the tubular extension 33 of the main body 31 are ball bearings 37. A suitable sealing means 38 is provided between the inner end of the tubular element 35 and the main body 31. The outer surface of the tubular element 35 is formed with a pulley 39 which is engaged by the belt 26 which, it will be remembered, was driven by the pulley 24 of the jack shaft 22. The outboard end of the tubular element 35 is provided with three legs 41 to the outer ends of which are fastened the plate element 36. Referring to Figure 3, which shows the workhead with the plate element 36 removed, it can be seen that the legs 41 occupy only a small portion of the periphery of the tubular element 35. The plate element 36 is provided with a longitudinal aperture 42 to

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permit the passage of the wheel therethrough. As is particularly evident in Figure 12, the inside surface of the plate 36 is provided with a carbide insert 43 which is adapted to engage one end of a workpiece 44, the workpiece being shown in the illustration as being the inner race of a miniature ball bearing whose inner bore surface is to be finished.

Mounted immediately inside the bore 32 of the main body 13 is a hollow spindle 45, there being suitable ball bearings 46 interposed between the bore 32 and the outer surface of the spindle. On the rearward end of the spindle is mounted a pulley 47 which is adapted to engage the belt 25 which, it will be recalled, is driven by pulley 23 of the jackshaft 22. Lying within the hollow spindle 45 is a tubular sheath 48, the spindle 45 and the sheath 48 being keyed together. It will be observed, however, that the spindle 45 is capable of rotation within the main body 13 but is not capable of longitudinal motion, whereas the sheath 48 revolves with the spindle 45, but is capable only of longitudinal motion relative thereto. A plug 49 and a coil spring 51 biases the sheath 48 to a right-hand position within the spindle 45. At its right-hand end the sheath 48 has attached thereto a hollow nose 52 which is provided with a carbide insert 53 (see Figure 12) which is adapted to engage the inside end of the workpiece 44, the nose and insert constituting a workpiece drive plate. Fastened to the front end of the tubular extension 33 of the main body 13 is a configured steel plate 54 and to the outboard side of this plate is fastened a stationary shoe holder 55 which is particularly well shown in Figure 3. The shoe holder is formed with a recess 56 in which is bolted a shoe 57 which has a carbide insert 58 adapted to engage the outside diameter of the workpiece 44, as is best shown in Figure 12. The portion of the carbide insert 58 which engages the outside diameter of the workpiece is suitably curved to fit the cylindrical surface of the workpiece snugly for sliding support thereof. An air slot 59 is formed on the outer face of the shoe holder 55 adjacent the plate element 36 of the workpiece clamp 34 and a longitudinal bore 61 enters the air slot at the radially outermost portion thereof. It should be noted that a passage 62 extends through the main body 13 of the workhead and is aligned with the bore in the shoe holder 55 for the admission of air thereto. A loading slot 63 is also formed in the surface of the shoe holder 55 and a segmental cut 64 is made in the shoe holder to act as an unloading chute.

Mounted within the right-hand end of the sheath 48 is a plug gauge 65 having a nose 66 which fits within the hollow nose 52 and which has at its outer end a small plug 67. At the left hand end of the sheath 48 is positioned a guide 68 and between the two resides a coil spring 69 which biases the plug gauge 65 toward the position in which the plug 67 resides within the bore of the workpiece 44, which is the condition shown in Figure 12. The plug gauge has attached to its left-hand end a gauge rod 71 which is attached, in a manner not shown, to the feed mechanism 19 to indicate the entrance of the plug 67 into the bore of the workpiece 44. A rubber diaphragm 72 is interposed between the plug gauge 65 and the inner surface of the sheath 48. Fastened to the outer end of the sheath 48 is a stop member 73 around which is slidably mounted a yoke 74 from which extends an actuating arm 75. The arm is mounted on a pivot 76 in its intermediate portion and attached at its outer end to the piston 77 of a hydraulic cylinder 78. The outer surface of the tubular element 35 of the workpiece clamp 34 is provided with a flange 79 in which are formed ratchet teeth 81, as is particularly evident in Figure 9.

Referring now to Figures 6, 7, and 8, which show the details of the loading mechanism 27, a bracket 82 is provided for attachment to the workhead 13. The one portion of the bracket has attached thereto a hydraulic

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cylinder 83 having a piston 84 with a piston rod 85, a screw 86 at one end serves as a stop member. Fastened to the side of the cylinder is a proximity switch 87 suitably mounted in a housing 88. To the other end of the bracket 82 is fastened a plate 89 which is adjustable therealong. On the bracket side of the plate 89 is fastened a cylinder 91 having a piston 92 which is normally biased to retracted position by a coil spring 93. The piston is provided with a piston rod 94 having a reduced end which is slidable in a bore in the plate 89. Mounted on the opposite side of the plate 89 from the cylinder 91 is a workpiece chute 95 having a groove 96 formed therein to hold a stack of workpieces. Adjacent the lower end of the chute 95 is a pick-up station 97 consisting of an inner member 98 and an outer member 99, the inner member being bolted to the plate 89. Recesses are formed at the sides of the outer member 99. Resilient fingers 102 are screwed to the sides of the outer member and are provided with grasping abutments 103 which normally reside in contacting engagement within the pick-up station 97. A groove 104 is formed in the inner surface of the outer member 99 and in this groove is slidably received a finger 105 formed of spring steel or the like and attached at its outer end to the piston rod 85. The inner end of the finger 105, which resides between the inner member 98 and the outer member 99, is provided with a slot 106 and with a square notch 107 at the extreme end. The notch has a width slightly less than the normal outside diameter of the workpiece 44, and a depth which is slightly greater than the outside radius of the workpiece. A bore 108 extends through the inner member 98 in substantial alignment with the piston 94 and terminates in the groove 104 formed in the inner surface of the outer member 99.

Referring now to Figures 9, 10, and 11, wherein are best shown the hydraulic and electrical interconnections in the controls of the machine, there is provided a high pressure line 109 and a return line 111 connected in the usual way to the hydraulic system of the machine which system includes a pump and a sump tank, not shown. A workhead valve 112 is provided of the solenoid-actuated plunger type having an input port 113 connected by a line 114 to the high pressure line 109. The valve is also provided with output ports connected together and by a line 115 to the return line 111. This valve is also provided with a port 116 to which is attached a line 117. Another port 118 is connected to a line 119. Line 119 is connected by a line 121 through a throttle 122 to one side of the motor 22 which is of the hydraulically-actuated type. The other side of the motor 22 is connected by a line 123 to one side of a throttle 124 the other side of which is connected to a port 125 in the hydraulic cylinder 83 which actuates the loading finger 105. A check valve 126 is connected across the throttle 124 and permits free flow of hydraulic fluid in the direction from the cylinder 83 to the motor 22. A sequence valve 127 has a port 128 connected by a line 129 to the return line 111. One end of its plunger is connected by a line 131 through a check valve 132 to the return line 111, the check valve being connected so that fluid flow may take place therethrough only between the valve 127 and the line 111. The valve 127 is of the hydraulically-operated type and is actuated by the difference in pressure across the ends of its plunger. The other end of the plunger is connected by a line 133 to the line 121 coming from the valve 112. The line 131 is connected to the line 121 in the portion thereof between the throttle 122 and the motor 22, so that the pressure across the ends of the plunger of the valve 127 is the pressure on opposite sides of the throttle 122 which pressure, because of the pressure drop through the throttle, would be indicative of the direction of flow through the line 121. The valve 127 is provided with two output ports which are connected together and by a line 134 to the line 121. The valve 127 is provided with a port 135 which is connected

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by a line 136 to an index cylinder 137. Another port 138 is connected by a line 139 through a check valve 141 to the transfer cylinder 91. The check valve is arranged so that flow may take place only in the direction from the cylinder 91 to the valve 127. The line 139 is also connected by means of a check valve 142 to a line 143 joining the index cylinder 137 to the outer end of the transfer cylinder 91 the check valve being arranged so that flow may take place only in the direction from the line 143 to the line 139. A line 144 connects the line 115 to the clamping cylinder 77 to ports of the clamping cylinder 77, other ports are connected by means of a line 145 to the line 117, while still another port of the cylinder 77 is connected by a line 146 to the cylinder 83. A line 147 connects the line 139 to a port of the clamping cylinder 77 at the extreme end thereof. When pressure from the line 147 throws the piston 78 of the cylinder 77 to its uppermost position, the fluid is permitted to flow from the line 146 to the line 144 and the line 115 to the return line 111.

Referring now to Figure 10, which shows the cross slide feed arrangement in the lower portion and the dressing arrangement in the upper portion, it can be seen that the high pressure line 109 and the return line 111 are associated with these circuits, as are the line 117 and the line 121 from the circuits shown in Figure 9. The lines 117 and 121 are connected to opposite ends of a dump valve 148. One port of the valve 148 has a line 149 connected thereto and another is connected to a line 151. The line 151 is also connected to one end of the feed rate cylinder 152 and to a port of an electro-hydraulic servo valve 153 having a coil 154; the electrical current passing through the coil 154 determines the setting of the valve and the position of the plunger therein. The other end of the cylinder 152 is connected by a line 155 to a port of the valve 153. The valve 153 is connected by a line 156 to the high pressure line 109. Two output ports of the valve 153 are connected by a line 157 to a line 158 leading to the return line 111 which is also connected to the line 149 coming from the valve 148. The cylinder 152 is provided with a piston 159 which is connected through a connecting rod 161 to one end of a lever 162 provided with a pivot 163 at its intermediate point. The other end of the lever 162 straddles one end of the core 164 of a lineal voltage differential transformer 165 which in turn is fastened to the base 11. Pressing against the end of the lever 162 which straddles the core 164 is the piston rod 166 of a piston 167 of a retraction cylinder 168. The piston 167 is provided at its other side with another piston rod 169 which is threadedly fastened to a nut 171, the nut being firmly fixed to the cross slide 18. One end of the cylinder 168 is connected by a line 172 to a port of a solenoid-actuated four-way valve 173. Another port of the valve 172 is connected by a line 174 to the other end of the cylinder 168. An input port of the valve 173 is connected by a line 175 which in turn is connected by a line 176 to the high pressure line 109. The output ports of the valve 173 are connected together by a line 177 which, in turn, is connected to the line 158 leading to the return line 111.

A compensation valve 178 is provided of the four-way solenoid-operated type having a coil 179 which is energized by a counter which counts the number of workpieces which have been finished, the counter being actuated by a final size switch which, in turn, is actuated by the gauge rod 71 in the workhead. The valve 178 is provided with another coil 181 which is energized by a table switch that indicates that the wheel has passed the dress position and is moving toward the workpiece. An input port of the valve 178 is connected to the line 176 and therefore to the high pressure line 109. Two output ports of the same valve are connected to the line 158 and therefore to the return line 111. One output port of the valve 178 is connected by a line 182 to the out-

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board end of a compensation cylinder 183. The compensation cylinder 183 has a piston 184 whose piston rod 185 is connected through a ratchet and pawl mechanism, not shown, to a truing tool attached to the cross slide 18 of the grinding machine, but which tool is also not shown. The advancement of the piston 184 therefore serves to advance the diamond by an increment preselected by the operator. The valve 183 has a port 186 which is connected by a line 187 to a truing tool cylinder 188 which is also formed to act as a valve. The line 187 and the line 182 are connected through a check valve 189 which is arranged to allow flow of oil only from the port 186 to the line 182. The line 187 is connected to the outboard end of the cylinder 188 and the cylinder is provided with a port 191 which is connected through a line 192 to the other output port of the valve 178. Proximity switches 193 and 194 are mounted at the extreme ends of the cylinder 188 to give signals indicative of the position of the piston in the cylinder. The cylinder 188 is provided with a piston 195 having a piston rod 196 which is connected to the truing tool to move it into dressing position when the piston is at the lower end of the cylinder. As is indicated in the drawing, the differential transformer 165 is connected by a lead 197 to a control 198. In the same way, the gauge rod 71 is shown as contacting a switch 199 which is connected from ground through a lead 201 to the control 198. Control 198 is connected to send a signal through a lead 202 to the coil 203 of the solenoid-actuated valve 112 (see Figure 9). The control 198 is also connected through a leader 204 to the coil 154 of the valve 153.

Referring now to Figure 11, a high pressure line 109 is connected to the input port 205 of a three-way electro-hydraulic servo valve 206 having a coil 207 by which the position of the plunger is controlled from a lead 208 to the control 198. The drain ports of the valve 206 are connected together and through a line 209 to the return line 111. One output port of the valve 206 is connected through a line 211 to one end of a table cylinder 212, whose piston 213 is connected to the table 16 to move it relative to the base 11. The other output port of the valve 206 is connected by a line 214 to the other end of the table cylinder 212. The high pressure line 109 is also connected through a line 215 to an input port of a three-way valve 216 which valve has an output port connected by a line 217 to the return line 111. An output port of the valve 216 is connected by a line 218 to one end of the gauge retraction cylinder 78 (see Figure 2). The piston 77 of this cylinder, as has been described, serves to withdraw the plug gauge 65 from the vicinity of the workpiece. The valve 216 is actuated by a coil 219 which is connected by a lead 221 to the control 198. Table cylinder 212 is attached to the table 16, as has been stated. The table 16 has mounted in its lower side a core 222 which becomes associated at different parts of the stroke with proximity switches 223 mounted in the base 11 and electrically connected to a control 224 which, in turn, is connected through the lead 208 to the coil 207 of the valve 206.

The operation of the apparatus will now be readily understood in view of the above description. Let us assume that a workpiece has just been finished and the wheelhead 12 has been moved to the right on the base 11 so that the wheel is removed from the area of the workhead 13. The finishing of the workpiece previously ground was indicated to the machine by the entrance of the plug gauge 65 into the workpiece and the movement of the gauge rod 71 to the right in Figure 2. This brought about the closure of the switch 199 and the receipt of a signal by the control 198. The control then acts to set the loading circuit into operation. First a signal is sent through the lead 204 to energize the coil 154 of the valve 153. This moves the piston 159 to the right in its cylinder 152. Oil drains from the cylinder through the line

155, through the valve 153, through the line 157, down the line 158 to the return line 111. Pressure oil enters the valve 153 through the line 156 and passes through the line 151 to the left hand side of the piston 159. The coil of the valve 173 is energized from the control box, thus reversing the flow of pressure oil to the cylinder 168 and causing the piston 167 to move to the right also. The movement of the piston 167 to the right takes place immediately upon the completion of the last workpiece and moves the wheel away from the workpiece surface. In any case, the table 18 is retracted and the piston 159 is moved to the left in the cylinder 152 so that it is ready for another feed cycle. Meanwhile, the loading circuits are operating. Control 198 signals through the lead 202 to energize the coil 203 of the valve 112. This reverses the flow of oil to the motor 22 and brings about the reversal in direction of the drive to the workhead. More importantly, it reverses the direction of movement of the flange 79 with its teeth 81 and causes it to move clockwise, as shown in Figure 9. The energization of the coil 203 in the valve 112 places pressure oil in the valve 119 which flows through the line 121 through the throttle 122 to the motor 22. At the same time this pressure oil enters the line 133 and presses the plunger of the valve 127 upwardly thus passing pressure oil into the line 139 so that it passes through the line 147 to the lower part of the cylinder 77 pressing the piston 78 upwardly and acting through the yoke 74 to draw the nose 52 away from the workpiece which is in the workhead. The moment that the pressure due to the spring 51 is released the workpiece is blown out of the workhead by the air in the passage 61 and the workpiece goes outwardly through the segmental cut 64 in the shoe holder 55. The reversal of flow of fluid to the motor 22 causes a change in the pressure differential at the ends of the plunger in the valve 127 and reverses that plunger from its normal position so that oil can flow from the cylinder 137 through the line 136 to the return line 111.

It is quite important that the workpiece be unclamped before reversal of the driving takes place for indexing. This is assured by the fact that the valve 112 is reversed (to ultimately reverse the direction of oil flow through the motor 22) so that pressure oil appears in the line 133 and line 121. This pressure is felt on the lower end of the plunger of the valve 127, but does not cause the plunger to move upwardly until the motor speed approaches zero preliminary to reversal. This is because the motor continues to cause a pressure at the upper end of the plunger due through line 131 due to motor inertia. When the motor speed reaches zero, however, this pressure will not be present and the plunger will move upwardly and permit pressure oil flow to the lower end of the clamp release cylinder 77. By assuring in this manner that the workpiece is not subjected to reverse driving it is possible to avoid scarring of the O.D. of the workpiece due to contact with the sharp edge of the shoe. The index piston 224 moves to the left against the spring pressure because of the pressure in the line 139 which extends into the cylinder 137 through a connecting line 225. The index pin 224 moves into engagement with the teeth 81 and serves to locate the workpiece clamp 34 so that the spaces between the posts 41 are positioned properly for the loading and unloading of workpieces. The movement of the index pin 224 to the left opens up a port so that pressure oil can flow from the line 225 through the line 143 to the transfer pin cylinder 91. This moves the piston 92 downwardly and, as is evident in Figure 7, pushes a new workpiece from the groove 96 of the chute 95 into position within the pickup station 97. The fingers 102 are pressed inwardly so their grasping abutments 103 are pressed against each other and the workpiece lies on top of them. The movement of the piston 92 in its cylinder uncovers the port permitting the flow of pressure oil from the line 143 to a line 226 connected at its other end to the extreme end of the loading

finger cylinder 83. The piston 84 moves within the cylinder carrying the finger 105 with it. In Figure 8 it can be seen that this action of the finger 105 downwardly causes it to engage the workpiece which lies on top of the abutments 103. The slot at the end of the finger causes the ends to be resilient so that the square notch 107 is pressed over the outside diameter of the workpiece. The finger 105 is considerably thinner than the axial length of the workpiece. The fact that the notch is slightly smaller in width than the outside diameter of the workpiece means that the slot 106 will permit the ends of the finger to spread slightly laterally to give a slight clamping action. Furthermore, the fact that the notch is slightly deeper than a radius of the workpiece means that the sides of the notch will be tangential to a diameter of the workpiece and stable clamping will take place. Further movement of the finger 105 in the same direction causes its curved ends to engage the abutments 103 of the fingers 102 and press them apart so that the finger 105 may pass between them. The fingers moving outwardly of the outer member 89. The finger slides along the groove 63 (see Figure 3) of the stationary shoe holder 55 until the workpiece comes in contact with the carbide insert 58 of the shoe 57. At that time the piston 84 is in the lowermost position in the cylinder 83, as it is shown in Figure 9. This is effective in two ways; first of all, the port 125 is uncovered and communication is possible between the line 226 and the line 123. At the same time the proximity switch 87 senses that the piston is in its lower position and generates a signal. This signal is carried to the control box through the lead 227 to the control 198 to indicate that the workpiece is in place. The control, therefore, sends a signal through the line 202 to the valve 112 and reverses the position of the plunger. This causes oil to flow in the opposite direction to the motor 22 and to drive the workhead in the grind direction of rotation. Before the motor comes up to speed, however, the flow of oil in the opposite direction has been indicated to the valve 127 and its plunger moves in the opposite direction, thus causing pressure oil to flow into the line 136 and pressing the indexing pin 224 to the right. The change of position of the valve 127 permits the flow of oil outwardly through the line 225, the line 139, and the line 134 and eventually to the return line 111. Pressure oil is released from the outer end of the cylinder 91 also, so that the oil returns to the return line through the line 143 and follows the same path as the drain oil from the cylinder 137. The piston 92 and its piston rod 94 are retracted by the spring 93. In the same way, oil is drained from the outer end of the cylinder 83 and pressure oil admitted to the lower end to carry the piston 84 to the upper end of the cylinder 83 and retract the finger from the workpiece. Before this happens, however, the reversal of the valve 112 has caused the pressure oil to appear at the upper end of the piston 78 of the gauge retraction cylinder 77. The nose 52, therefore, presses to the right against the end of the workpiece under the action of the spring 51 and the workpiece is clamped between the carbide inserts 43 of the clamping plate 36 and the carbide insert on the nose 52. The gauge 67 is pressed to the right under the action of its spring 69 and attempts to enter the workpiece until the grinding progresses to the stage where it may do so. Incidentally, it should be noted that during the reciprocations of the wheel in the workpiece during the grinding operation the gauge rod 71 is moved so that the plug 67 is well away from the workpiece during every approach of the wheel into the workpiece. This is accomplished by the common mechanical linkages used with plug gauges and is a common mechanism used in the art. Now, the pressure oil in the line 117 and, therefore, in the line 145 presses the piston downwardly. This serves to connect the line 145 with the line 146 leading the loading finger cylinder 83, thus bringing about the retraction of the finger. The retraction of the finger, there-

fore, takes place only after the workpiece has been firmly clamped. By this time the motor 22 has come up to speed and is driving the workhead at its grinding speed.

The valve 216 causes the reversal of flow of oil to the gauge retraction cylinder at the end of every cycle. The energization of the valve 216 is by the energization of the coil 219 through the lead 221 coming from the control 198. The movement of the table 16 takes place, of course, by means of the cylinder 212. The rate of feed of oil to this cylinder and the direction thereof is determined by the valve 206 which is under the control of the coil 207. The proximity switches 223 sense the position of the table and act through the control 224 and the lead 208 to change the energization of the coil 207 to set the valve in the desired position. At certain times during the cycle the proximity switches will indicate that a change of speed is necessary or a change of direction and this is accomplished by the valve 206 under instructions from the control 224. Once the workpiece has been clamped in place the wheel advances into the workpiece under the action of the cylinder 212. The wheel must then be fed laterally into the workpiece surface for the grinding operation. This is accomplished by the movement of the nut 171 under the control of the piston rod 169 and the piston 167 of the cylinder 168. When the workpiece has been clamped and the feeding cycle is about to begin, this fact is signaled by a control 198 through the lead 228 for the energization of the coil 229 of the valve 173. This causes pressure oil to enter the left-hand side of the cylinder 168 and cause the piston 167 to be pressed to the left. However, the piston rod 166 strikes the upper end of the lever 162 and the desired motion of the cross slide is not permitted until the piston 159 permits this motion. The admission of oil to the cylinder 152 is determined by the valve 153 whose setting is proportional to the energization of the coil 154 in response to a signal from the control 198 through the lead 204. The control 98, in turn, receives a signal from the lineal voltage differential transformer 165 which senses the position of the core 164 and thus senses the position of the cross slide 18 relative to the base 11. The control, therefore, tells the valve 153 just what the feed rate should be so that it can pass that amount of oil to the cylinder 152. The grinding cycle continues until once again the plug 67 is able to enter the workpiece and terminate the cycle.

Returning again to the beginning of the loading cycle, the closure of the switch 199 by the gauge rod 71 has energized the counter 231 which in turn energizes the coil 179 of the valve 178. According to the selection of the operator, the counter will energize the coil 179 only after a preset number of workpieces have been finished. Sometimes it is desirable to dress after every workpiece is finished. In any case the energization of the coil 179 reverses the valve 178 and causes flow of pressure oil through the line 182 to the cylinder 183 thus moving the piston 184 to the left and causing the piston rod 185 to operate through the usual dressing compensation mechanism to move the diamond into a forward position where it will remove a small amount of abrasive from the surface of the wheel at the proper time. Now the entry of the gauge plug into the workpiece has also caused the retraction of the wheel from the work and an extended traverse to its position remote from the workhead. Therefore, the reversal of the valve 178 may safely permit the introduction of pressure oil through the line 187 because of the left-hand position of the piston 184 permitting passage of pressure oil from the line 182 to the line 187. Therefore, the pressure oil appears above the piston 195 in the cylinder 188 and causes the movement of the piston to bring the dressing tool down into dressing position. The proximity switch 194 senses the position of the truing tool and acts through a lead 232 to send a signal to the control 224 which will permit the wheelhead to be moved toward the workpiece

past the truing tool. The passage of the wheel past the truing tool will be indicated to the control 224 which, in turn, will send a signal to a lead 233 to energize the coil 181 and to again reverse the valve 178. This has the effect of causing pressure oil to appear under the piston 195 of the cylinder 188 and to retract the truing tool.

In a general way, then, it will be understood that the indexing of the workhead and the operation of the loading circuit for placing into a workpiece in position to be ground takes place while the wheelhead is on an extended traverse and in its most remote position from the workhead. The gauge retraction circuit in Figure 11 operates at the end of every grinding cycle so that the plug 67 is safely away from the workpiece. The dressing and compensation circuit operate during the loading portion of the cycle although, of course, the dressing is not completed until the wheel is ready to enter the work. Dressing may take place, as is usual practice, at almost any time during the cycle. Quite often it is used between the rough grind and the finish grind. The cross slide feed circuit as shown in Figure 10 is only operative while the loading circuits are static. As has been shown, the feeding operation is generally under the control of the differential transformer 165 which at any time senses the position of the cross slide 18. In the preferred embodiment, however, the end of the grinding operation is indicated by the entrance of the plug into the workpiece and the gauge rod 71 closing the switch 199. The longitudinal movement of the wheelhead, however, is controlled by the proximity switches 223.

It should be noted also that, in introducing a workpiece into the workhead, the workpiece is grasped at all times so that it cannot be blown out of the workhead prematurely by the air in the groove 59. The workpiece is grasped by the finger 105 until it strikes the carbide insert 58 of the shoe 57 and is then clamped between these two elements. The finger 105 is not withdrawn until the workpiece is clamped between the plate element 36 of the workpiece clamp 34 and the hollow nose 52 which also acts as the driving plate for the workpiece. Of course, once the grinding operation has been performed and the clamping pressure relieved the air is able to blow the workpiece out through the segmental gap 64 into a chute or the like leading to a workpiece storage container. Incidentally, the workpiece during the grinding operation is pressed downwardly on to the shoe 57 because of a slight eccentricity of the aperture 42 and the carbide inserts 43 of the plate member 36 thus producing a slight skewing action between the surface of the workpiece and the surface of the carbide insert which action produces friction forces directed toward the shoe 57.

One interesting aspect of the present invention lies in the fact that the workpiece is driven from both ends. Both the drive plate and the clamp plate are driven; this is in contrast with the prior art arrangements in which the clamping plate is mounted for free rotation, but is driven by the workpiece which, in turn, is driven at the other end by the drive platen. The present novel arrangement has two advantages. First, half the driving traction is provided at each end, resulting in less distortion of the workpiece. Secondly, the outboard clamping plate can have the eccentricity necessary to drive the workpiece toward the supporting shoe. Since the inboard drive plate can now be eccentric with the bore in the workpiece, the gage can be mounted firmly on bearings within the workhead and drive plate, rather than on a long cantilever gage rod as in the past. The cantilever arrangement of the prior art permitted the gage rod and gage to bend slightly so that every attempt of the gage to gain admission to the bore resulted in a substantial blow of the gage against the end of the workpiece at one side of the bore; this resulted in uneven grinding of the bore.

It is obvious that minor changes may be made in the form and construction of the invention without departing from the material spirit thereof. It is not however de-

sired to confine the invention to the exact form herein shown and described but it is desired to include all such as properly come within the scope claimed.

The invention having been thus described what is claimed as new and desired to secure by Letters Patent is:

1. A grinding machine, comprising a loading mechanism bracket, a finger slidably mounted on the bracket for movement in a line of action lying in a first plane, a chute formed to carry workpieces serially in a line of action lying in a second plane parallel to and spaced from the first plane and at a right angle to the axes of the workpieces, the chute being mounted on the bracket so that the projection of its line of action on the first plane intersects the line of action of the finger, a passage joining the two lines of action in the area of the said intersection and extending at a right angle to the two planes, a transfer pin slidable in line with the passage for transferring workpieces axially through the passage from the chute to the line of action of the fingers, and resilient fingers moveable into the path of the finger to support each workpiece until the finger arrives opposite the passage to engage the workpiece.

2. A grinding machine, comprising a loading mechanism bracket, a finger slidably mounted on the bracket for movement in a line of action lying in a first plane, a chute formed to carry workpieces serially in a line of action lying in a second plane parallel to and spaced from the first plane the projection of the line of action of the chute on the first plane forming an intersection with the line of action of the finger, and at a right angle to the axes of the workpieces a passage joining the two lines of action in the area of the said intersection and extending at a right angle to the two planes, a transfer pin slidable in line with the passage for transferring workpieces axially through the passage from the chute to the line of action of the finger, and opposed fingers resiliently biased together in the path of the finger to support each workpiece until the finger arrives opposite the passage to engage the workpiece, the end of the finger being slotted and formed with a square notch to embrace and grasp the outside diameter of a circular workpiece, the ends of the finger being formed to separate the opposed fingers upon continuation of movement after grasping the workpiece.

3. A grinding machine, comprising a workhead main body having a tubular extension and a bore coaxial therewith, a workpiece clamp rotatably mounted on the extension, a drive plate rotatably mounted in the bore, a motor for driving the clamp and plate so that they in turn transmit driving power to a workpiece, a spring normally biasing one of the clamp and plate toward the other to grasp and rotate the workpiece, a stationary shoe holder mounted between the clamp and plate, the holder having a shoe to support and locate the workpiece, and means to separate the clamp and plate on occasion, the clamp having a tubular member coaxial with the tubular extension of the main body and a clamp plate mounted over one end in opposition to the drive plate, the clamp plate being joined to the tubular member by relatively thin legs to provide openings therebetween, one side of the shoe holder residing closely adjacent the inner surface of the clamp plate, the shoe holder having grooves formed on the said one side to form passages with the said inner surface of the clamp plate for the introduction and removal of workpieces, the shoe holder having an aperture therethrough centrally thereof in which the workpiece lies during grinding, the drive plate having a nose extending into the aperture to contact the workpiece located in the aperture, a loading mechanism bracket, a first finger slidably mounted on the bracket for movement in a line of action lying in a first plane, a chute formed to carry workpieces serially and having a line of action lying in a second plane parallel to and spaced from the first plane and at a right angle to the axes of the workpieces, a passage joining the two

lines of action and extending at a right angle to the two planes, a transfer pin slidable in line with the passage for transferring workpieces axially through the passage from the chute to the line of action of the finger, opposed fingers resiliently biased together in the path of the said first finger to support each workpiece until the said finger arrives opposite the passage to engage the workpiece, the end of the said finger being slotted and formed with a square notch to embrace and grasp the outside diameter of a circular workpiece, the end of the first finger being formed to separate the said opposed fingers upon continuation of movement after grasping the workpiece.

4. A grinding machine, comprising a workhead main body having a tubular extension and a bore coaxial therewith, a workpiece clamp rotatably mounted on the extension, a drive plate rotatably mounted in the bore, a motor for driving the clamp and plate, a first means including a spring normally biasing one of the clamp and plate toward the other to grasp and rotate a workpiece, a stationary shoe holder mounted between the clamp and plate, the holder having a shoe to support and locate the workpiece, and means to remove the spring bias of the clamp and plate on occasion, the clamp having a tubular member coaxial with the tubular extension of the main body and a clamp plate mounted over one end in opposition to the drive plate, the clamp being joined to the tubular member by relatively thin legs to provide openings therebetween, one side of the shoe holder residing closely adjacent the inner surface of the clamp plate, the shoe holder having grooves formed on the said one side to form passages with the said inner surface of the clamp plate for the introduction and removal of workpieces, the shoe holder having a large aperture therethrough centrally thereof and which the workpiece lies during grinding, the drive plate having a nose extending into the aperture to contact the workpiece located in the aperture, one of the grooves in the shoe holder forming a passage permitting the finger to pass radially between the plates, a first hydraulic cylinder to render the said first means inoperative, means providing an air stream to remove the workpiece from between the plates when the first means is inoperative, a finger movable to place a workpiece between the plates when the said first means is inoperative, the finger being actuated by a second hydraulic cylinder, and a valve rendered operative to admit hydraulic fluid to the second cylinder only after the first cylinder has been substantially actuated, thus assuring that the finger is not removed from the workpiece after it is placed between the plates until the said first means is rendered operative, an index means associated with the workhead to align the said passage with the finger, and means assuring that the indexing means is operated before the finger is moved toward the passage.

5. A grinding machine, comprising a workhead having a driving plate and a clamping plate, a first means for moving one of the plates toward the other to grasp a workpiece, a first hydraulic cylinder to render the first means inoperative, means providing an air stream to remove a workpiece from between the plates when the first means is inoperative, a loading mechanism bracket, a finger slidably mounted on the bracket for movement in a line of action lying in a first plane, a chute formed to carry workpieces serially and having a line of action lying in a second plane parallel to and spaced from the first plane, a passage joining the two lines of action and extending at a right angle to the two planes, a transfer pin slidable in line with the passage for transferring workpieces through the passage from the chute to the line of action of the finger, opposed fingers resiliently biased together in the path of the finger to support each workpiece until the finger arrives opposite the passage to engage the workpiece, the end of the finger being slotted and formed with a square notch to embrace and grasp the outside diameter of a circular workpiece, the end of

the finger being formed to separate the opposed fingers upon continuation of movement after grasping the workpiece, the finger being actuated by a second hydraulic cylinder, a valve rendered operative to admit hydraulic fluid to the second cylinder only after the first cylinder has been substantially activated thus assuring that the finger is not removed from the workpiece after it is placed between the plates until the said first means is rendered operative, a second passage permitting the finger to pass radially between the plates, an indexing means associated with the workhead to align the said second passage with the finger, and means assuring that the indexing means is operated before the finger is moved toward the said second passage.

6. A grinding machine, comprising a workhead main body having a tubular extension and a bore coaxial therewith, a workpiece clamp rotatably mounted on the extension, a drive plate rotatably mounted in the bore, a motor for driving the clamp and plate, a spring normally biasing one of the clamp and plate toward the other to grasp and rotate a workpiece, a stationary shoe holder mounted between the clamp and plate, the holder having a shoe to support and locate the workpiece, and means to separate the clamp and plate on occasion, the clamp having a tubular member coaxial with the tubular extension of the main body and a clamp plate mounted over one end in opposition to the drive plate, the clamp plate being joined to the tubular member by relatively thin legs to provide openings therebetween, one side of the shoe holder residing closely adjacent the inner surface of the clamp plate, the shoe holder having grooves formed on the said one side to form passages with the said inner surface of the clamp plate for the introduction and removal of workpieces, the shoe holder having an aperture therethrough centrally thereof in which the workpiece lies during grinding, the drive plate having a nose extending into the aperture to contact the workpiece located in the aperture, a loading mechanism bracket, a finger slidably mounted on the bracket for movement in a line of action lying in a first plane, a chute formed to carry workpieces serially and having a line of action lying in a second plane parallel to and spaced from the first plane, a passage joining the two lines of action and extending at a right angle to the two planes, a transfer pin slidable in line with the passage for transferring workpieces through the passage from the chute to the line of action of the finger, opposed fingers resiliently biased together in the path of said finger to support each workpiece until said finger arrives opposite the passage to engage the workpiece, the end of the said finger being slotted and formed with a square notch to embrace and grasp the outside diameter of a circular workpiece, the end of the finger being formed to separate the said opposed fingers upon continuation of movement after grasping the workpiece, a first hydraulic cylinder to render the said spring inoperative to bias the plates together to grasp a workpiece, means providing an air stream to remove a workpiece from between the plates when the said spring is rendered inoperative, one of the grooves in the shoe holder forming a second passage permitting the finger to pass radially between the plates, the said finger being actuated by a second hydraulic cylinder, a valve rendered operative to admit hydraulic fluid to said second cylinder only after the first cylinder has been substantially activated thus assuring that the finger is not removed from the workpiece after it is placed between the plates until the said spring is rendered operative to grasp the workpiece, an indexing means associated with the workhead to align the said passage with the finger, and means assuring that the indexing means has operated before the finger is moved toward the said second passage.

7. A grinding machine, comprising a workhead main body having a tubular extension and a bore coaxial therewith, a workpiece clamp rotatably mounted on the extension,

sion, a drive plate rotatably mounted in the bore, a motor for driving the clamp and plate, a first means including a spring normally biasing one of the clamp and plate toward the other to grasp and rotate a workpiece, a stationary shoeholder mounted between the clamp and plate, the holder having a shoe to support and locate the workpiece and means to remove the spring bias of the clamp and plate on occasion, the clamp having a tubular member coaxial with the tubular extension of the main body and a clamping plate mounted over one end in opposition to the drive plate, the clamping plate being joined to the tubular member by relatively thin legs to provide openings therebetween, one side of the shoeholder residing closely adjacent the inner surface of the clamping plate, the shoeholder having grooves formed on the said one side to form passages with the said inner surface of the clamping plate for the introduction and removal of workpieces, the shoeholder having a large aperture therethrough centrally thereof in which the workpiece lies during grinding, the drive plate having a nose extending into the aperture to contact the workpiece located in the aperture, one of the grooves in the shoeholder forming a passage permitting a workpiece to pass radially between the plates, a first hydraulic cylinder to render the said first means inoperative, means providing an air stream to remove the workpiece from between the plates when the first means is inoperative, feed means movable to place a workpiece between the plates when the said first means is inoperative, the feed means being actuated by a second hydraulic cylinder, and a valve rendered operative to admit hydraulic fluid to the second cylinder only after the first cylinder has been substantially actuated, thus assuring that the said feed means is not removed from the workpiece after it is placed between the plates until the said first means is rendered operative, an index means associated with the workhead to align the said passage with the feed means, and means assuring that the indexing means is operated before the feed means is moved toward the passage.

8. A grinding machine, comprising a workhead main body having a tubular extension and a bore coaxial therewith, a workpiece clamp consisting of a tubular member and a clamping plate both rotatably mounted on the extension, a drive plate rotatably mounted in the bore, drive means on the tubular member of the clamp, drive means on the drive plate, resilient means normally biasing one of the clamp and plate toward the other to grasp and rotate the workpiece, a stationary shoeholder mounted between the clamp and plate, the holder having a shoe to support and locate the workpiece, and means to remove the resilient bias of the clamp and plate on occasion, the tubular member of the clamp being coaxial with the tubular extension of the main body and the clamping plate of the clamp being mounted at one end in opposition to the drive plate, the clamping plate being joined to the tubular member by relatively thin legs to provide openings therebetween, one side of the shoeholder residing closely adjacent the inner surface of the clamp plate, the shoeholder having grooves formed on the said one side to form passages with the said inner surface of the clamping plate for the introduction and removal of workpieces, the shoeholder having an aperture therethrough centrally thereof in which the workpieces lie during grinding, the drive plate having a nose extending into the aperture to contact the workpiece located in the aperture.

References Cited in the file of this patent

UNITED STATES PATENTS

1,300,051	Townsend	Apr. 8, 1919
2,696,986	Grobey	Dec. 14, 1954
2,723,499	Dix	Nov. 15, 1955
2,754,641	Bidwell	July 17, 1956
2,828,588	Durland	Apr. 1, 1958