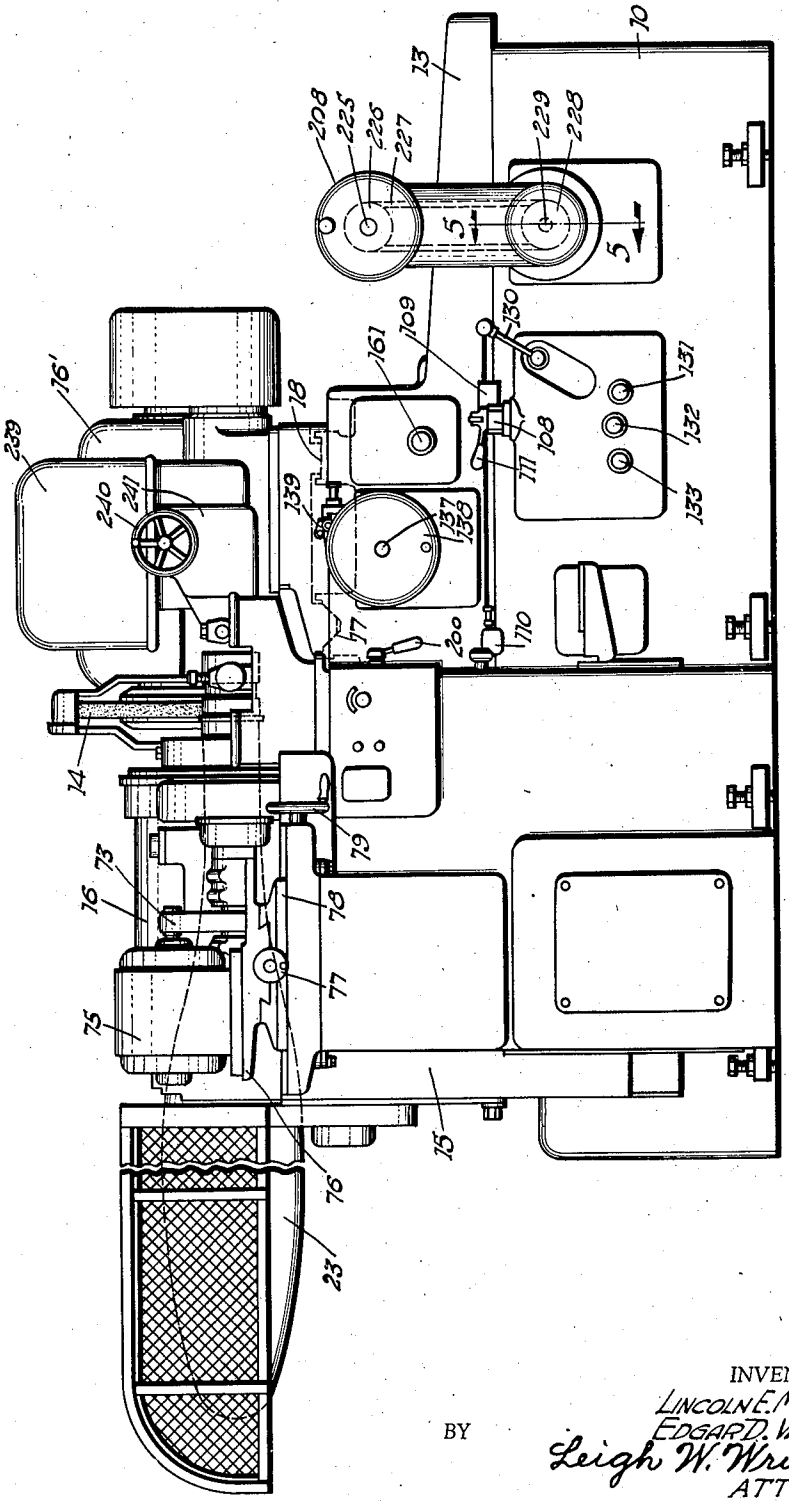
Jan. 30, 1945. L. E. MEHLHOPE ET AL 2,368,315

GRINDING MACHINE

Filed March 29, 1943 6 Sheets-Sheet 1

Fig. 1



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GRINDING MACHINE

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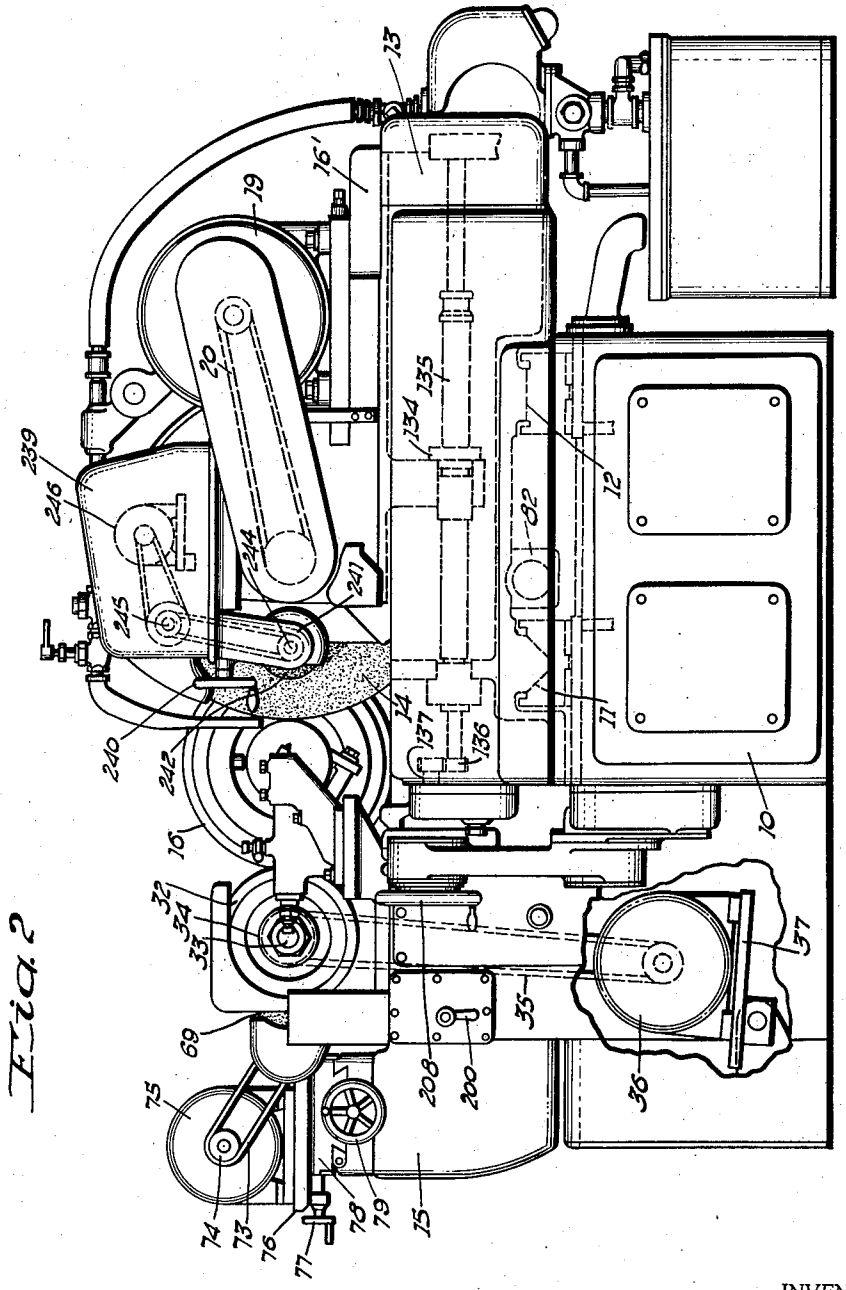


Fig. 2

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GRINDING MACHINE

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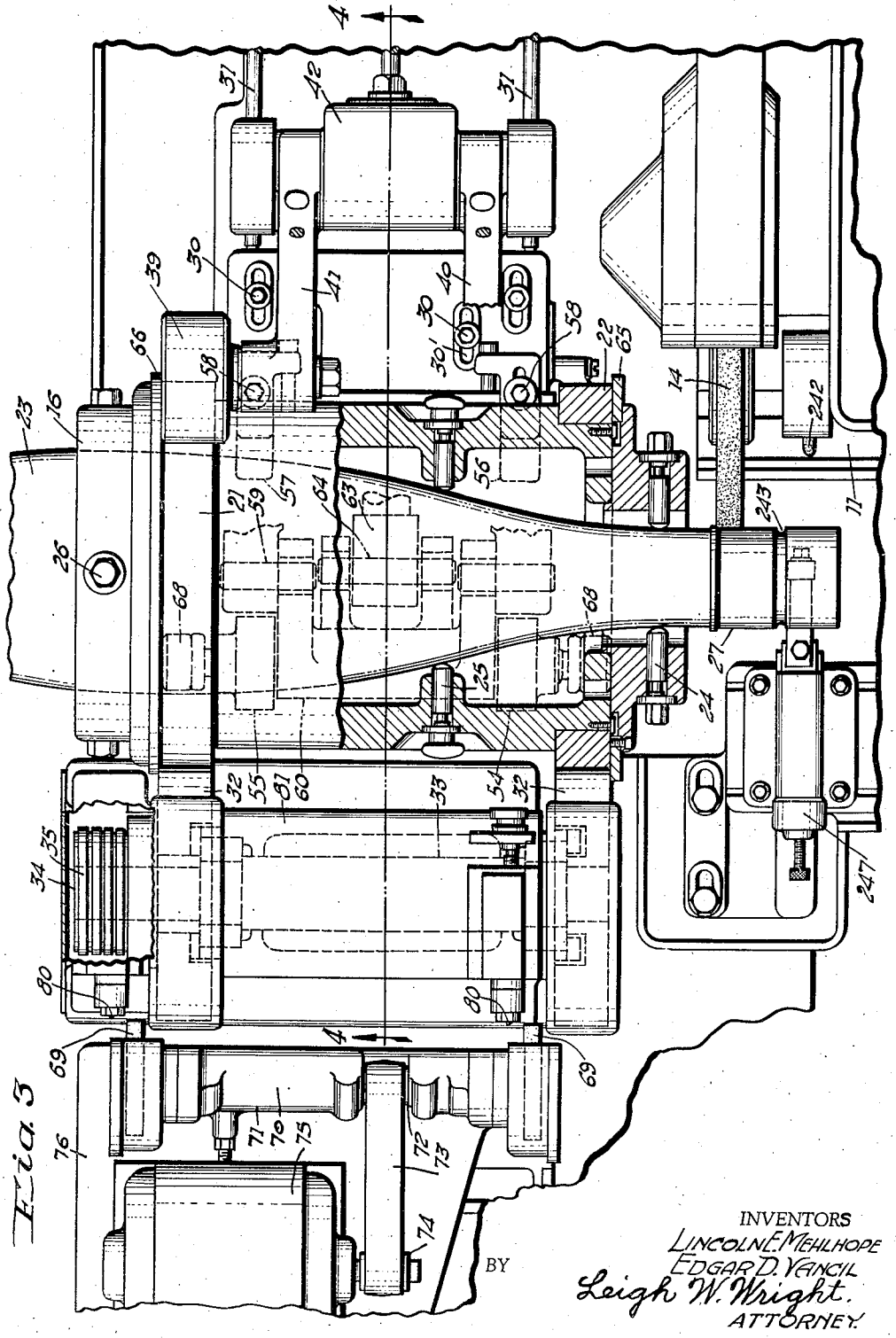


Fig. 3

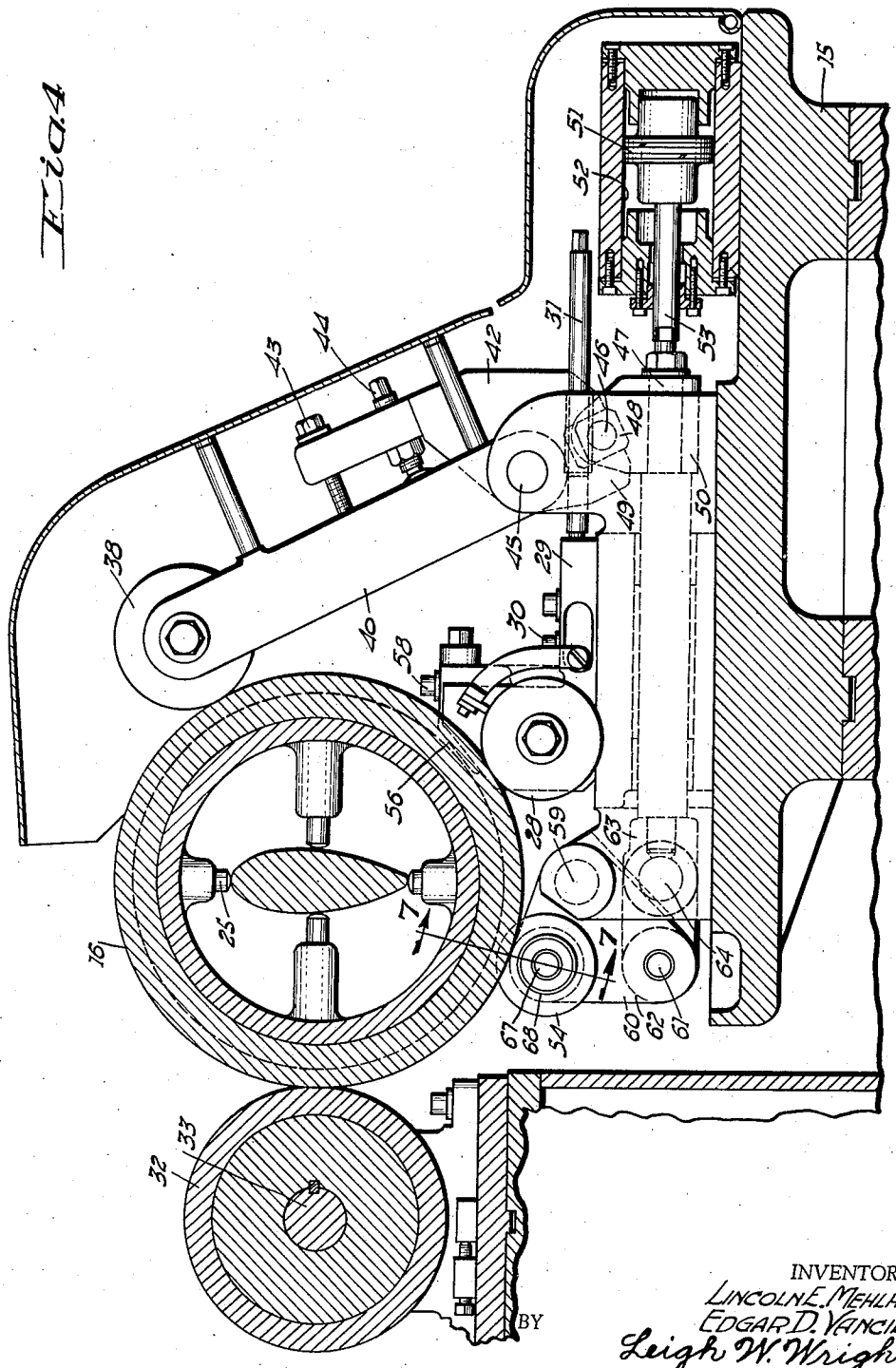
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GRINDING MACHINE

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Fig. 4



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GRINDING MACHINE

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Fig. 5

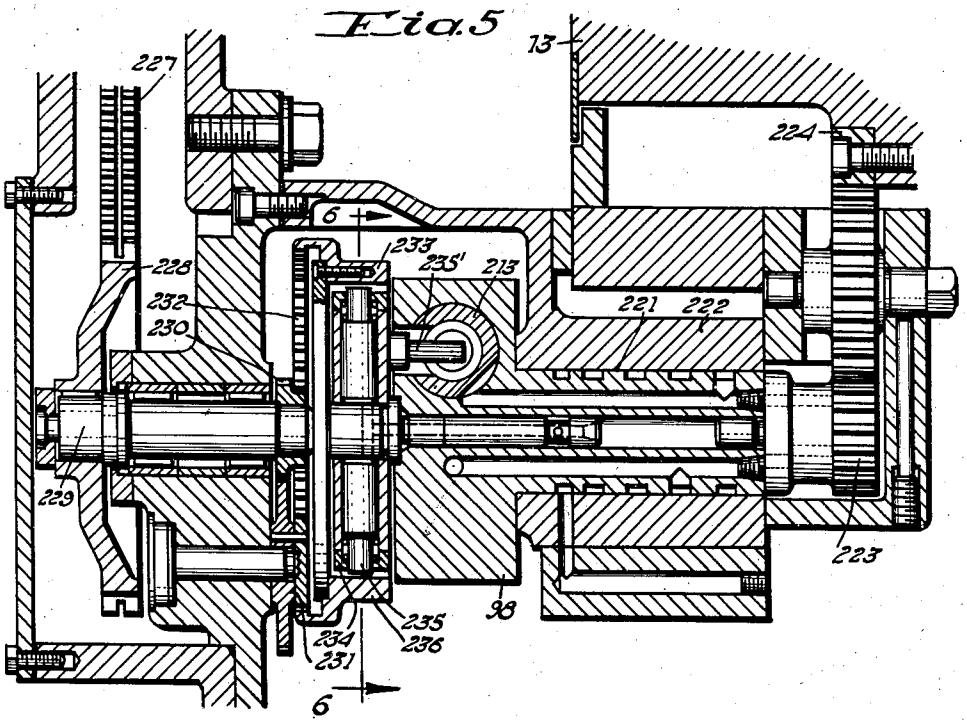
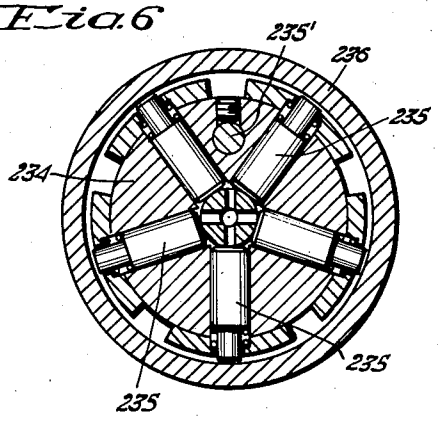


Fig. 6



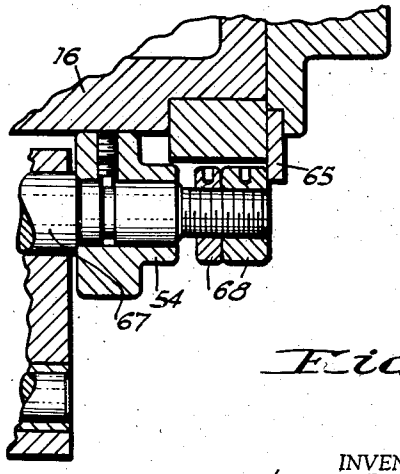


Fig. 7

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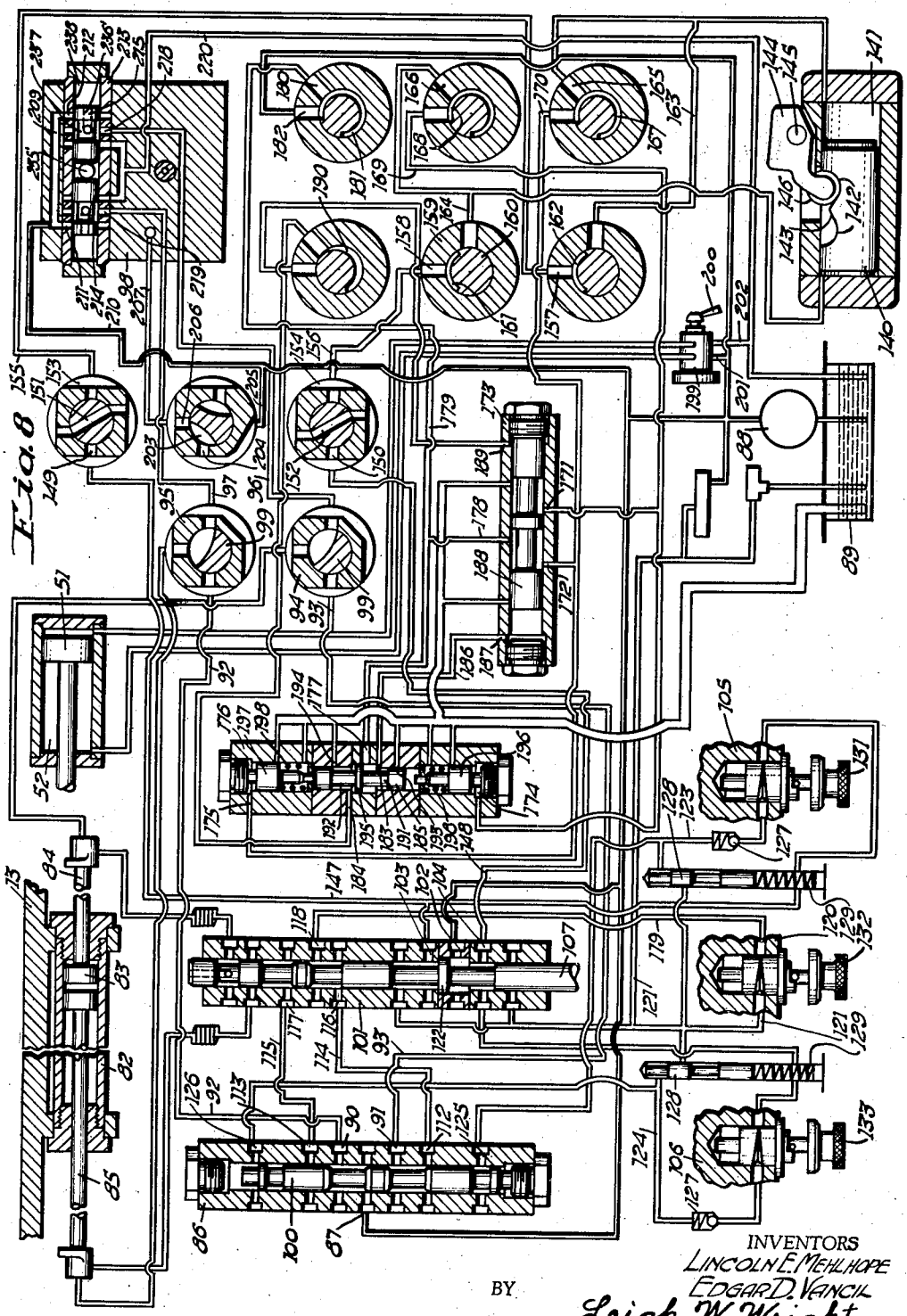
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GRINDING MACHINE

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Fig. 8



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Patented Jan. 30, 1945 2,368,315

UNITED STATES PATENT OFFICE

2,368,315

GRINDING MACHINE

Lincoln E. Mehlhope and Edgar D. Vancil, Cincinnati, Ohio, assignors to The Cincinnati Milling Machine Co., Cincinnati, Ohio, a corporation of Ohio

Application March 29, 1943, Serial No. 481,036

7 Claims. (Cl. 51—3)

This invention relates to machine tools and more particularly to improvements in grinding machines.

One of the objects of this invention is to provide an improved machine for performing cylindrical grinding operations on work which cannot be conveniently supported on centers in conventional grinding machines because of its shape or construction.

Another object of this invention is to provide a grinding machine which is organized to receive a work shuttle and rotatably drive it in precision relationship to a grinding wheel so that a cylindrical surface on a work piece held by the shuttle may be accurately ground.

A further object of this invention is to provide a grinding machine with regulating wheel driving means for a work supporting shuttle, together with auxiliary means for grinding or truing said wheels in situ.

Still another object of this invention is to provide a grinding machine with means for performing a cylindrical grinding operation and auxiliary means for performing a supplementary grinding operation in one setup of the work piece.

Other objects and advantages of the present invention should be readily apparent by reference to the following specification, considered in conjunction with the accompanying drawings forming a part thereof and it is to be understood that any modifications may be made in the exact structural details there shown and described, within the scope of the appended claims, without departing from or exceeding the spirit of the invention.

Referring to the drawings in which like reference numerals indicate like or similar parts:

Figure 1 is a front elevation of a machine tool embodying the principles of this invention.

Figure 2 is a side elevation of the machine shown in Figure 1.

Figure 3 is a plan view partly in section showing the relationship of the work holding and driving mechanism.

Figure 4 is a section in elevation on the line 4—4 of Figure 3.

Figure 5 is an enlarged detail section on the line 5—5 of Figure 1.

Figure 6 is a section on the line 6—6 of Figure 5.

Figure 7 is a detail view on the line 7—7 of Figure 4.

Figure 8 is a diagram of the hydraulic control circuit for the machine.

It often occurs that cylindrical grinding operations have to be performed on cylindrical surfaces which form part of a work piece which is of such an odd shape that it does not provide its own centers upon which it may be rotated, and therefore cannot be supported in the conventional center type grinding machine.

In the metal-working industry it is common practice in forming or producing cylindrical surfaces to support the work for rotation about an axis which will generate the desired surface. This is accomplished by forming center holes in the ends of the work to define the axis and to be utilized in supporting the work during rotation. The shape of some work, however, is such as to prohibit this practice, usually because they do not provide the necessary surface in which the holes may be formed. Therefore other means must be resorted to in order to support the work for rotation about the desired generating axis.

In the present instance, the work is mounted in a shuttle which has a pair of spaced journals whereby it may be supported for rotation and the axis of these journals determines the generating axis. The work is secured in the shuttle in such position that the axis of the surface to be generated is co-incident with the axis of rotation of the shuttle. Obviously considerable time is involved in performing this operation and where several machining operations are to be performed, it is desirable that the work remain in the same shuttle and the shuttle transferred from one machine to another, thereby insuring greater accuracy and coordination between the several machining operations as well as the saving in time.

The present machine is so contrived and designed that it may receive these shuttles and utilize them for rotating work contained therein in performing a cylindrical grinding operation on the work.

In general, the machine comprises a bed 10 which is somewhat L-shaped and one portion of the bed is provided with a pair of guideways 11 and 12 as shown in Figure 2 for supporting a slide 13 which carries a grinding wheel 14 that is capable of two-directional movement. The other portion 15 of the bed is utilized for supporting and driving a removable shuttle, indicated generally by the reference numeral 16, and shown more particularly in Figure 3. The grinding wheel is supported on a cross slide 16' which, in turn, is supported in guideways 17 and 18 formed in the slide 13 for cross movement relative thereto. A prime mover 19 mounted on the slide 16' as

shown in Figure 2 is connected by a suitable belt 20 for driving the grinding wheel 14.

Since the shuttle is removable it is necessary to provide separable bearing means whereby the shuttle may be placed in the bearing and then the bearing closed to hold it in a fixed rotatable position while power is applied to it to effect the rotation.

As more particularly shown in Figure 3, the shuttle 16 is provided with spaced journals 21 and 22. The shuttle itself constitutes no part of the present invention, but to facilitate understanding of this invention it may be said that the work piece, which is indicated by the reference numeral 23, is secured in the proper position within the shuttle by three sets of clamping members indicated generally by the reference numerals 24, 25 and 26 which are spaced longitudinally of the shuttle in the most advantageous positions to hold the work rigid with the shuttle whereby any rotative movement imparted to the shuttle will impart rotation to the work. The reference numeral 27 indicates generally the cylindrical surface on the work piece which is to be ground by the grinding wheel 14.

Since the grinding wheel 14 must be reciprocated in order to grind the surface 27 it will be obvious that the shuttle 16 must be supported for rotation about an axis parallel to the axis of the guideways 11 and 12 upon which the slide 13 moves to effect reciprocation of the grinding wheel.

To this end, the portion 15 of the bed is provided with a pair of support rollers 28 which are properly spaced to engage the journals 21 and 22. These rollers are rotatably supported on a pillow block 29 which is adjustable and which may be clamped in adjusted position by a plurality of clamping bolts 30 passing through elongated slots 30' in the pillow block.

In addition, the pillow block may be positively held by a pair of adjustable backing-up screws 31. These screws serve to square up the pillow block and insure that the rollers are aligned in parallelism with the guideway 11. The shuttle 16 is also held in position by a pair of regulating wheels 32 which also engage the journals and these wheels are supported on a shaft 33 which has a driving pulley 34 secured to one end thereof. This pulley is operatively connected by a series of belts 35 to a drive motor 36 mounted on an adjustable base 37 located in the bed of the machine as shown in Figure 2.

The regulating or driving wheels 32 drive the shuttle 16 by friction and therefore it is necessary to hold the shuttle against any lateral movement during rotation and also to insure that the axis of rotation of the work does not shift which, of course, would result in eccentricities in the finished surface. This is accomplished by providing a pair of removable rollers 38 and 39, Figures 3 and 4, which also engage the journals 21 and 22 and these rollers are supported for rotation on the ends of arms 40 and 41. These arms are connected to an operating crank 42 by a clamping bolt 43 and an adjustable stop 44. By adjusting the stop 44 and then pulling the lever 40 against the stop by the screw 43 the angle of the arm 40 may be changed relative to the angle of the crank 42.

The crank and the arms are supported for rotation on a shaft 45 and the crank is connected to an operating pin 46 which is carried by a reciprocable rod 47. The pin has a square block 48 mounted on it which fits in the bifurcated end 49 of the crank 42. The pin 46 is carried by a block 50 which is attached to the rod 47. The rod is reciprocated by a piston 51 which is slidably mounted in a cylinder 52 which is integrally attached to the bed. The piston is connected by a piston rod 53 to the sliding rod 47. It will thus be obvious that when fluid pressure is admitted to the right hand end of the cylinder 52 that the crank 42 will be rotated in a clockwise direction, removing the rollers 38 and 39 from engagement with the shuttle. Similarly, when pressure is admitted to the left end of cylinder 52 the rollers will move in a counter clockwise direction into engagement with the shuttle and thereby hold it into frictional engagement with the regulating wheels 32 for actuating purposes.

Since the surfaces of the support rolls 28 must be carefully protected, means have been provided for lifting the shuttle off of these rolls when the shuttle is to be removed, and for receiving and supporting the shuttle when it is inserted in the machine so as to prevent any denting or flattening of the roller surfaces which might interfere with the concentric rotation of the shuttle. This means comprises a pair of lift rollers 54 and 55 which are so spaced and positioned as to engage the peripheral surface 56 of the shuttle which is between the journals 21 and 22. In addition, the pillow block 29 is provided with a pair of receiving pads 56 and 57 which are adjustably mounted in position and clamped as by bolts 58.

These pads, it will be noted from Figure 4, are located above the rollers 28 in such position that when the lift rollers 54 are rotated about the pivot shaft 59 after the clamp rollers 38 have been removed, the shuttle will be rotated off of the support rollers 28 and onto the pads 56. The lift rollers are oscillated in a clockwise direction to effect this and they remain in position while the shuttle is removed and a new one placed in position. This insures that the shuttle is properly supported before it is lowered onto the support rollers 28.

The lift rollers 54 are carried by a crank 60 which is operatively connected by a pin 61 and a connecting link 62 to the rod 47 which has a bifurcated member 63 integral therewith for connection by pin 64 to the link. It will now be obvious that the lift rollers 54 will move simultaneously with the clamp rollers 38 in a direction to lift the shuttle after the clamp rollers are removed, and to lower the shuttle before the clamp rollers move into clamping position.

It is, of course, necessary to hold the work holder or shuttle against axial movement during the grinding operation and to this end the shuttle is provided with flanges 65 and 66 located adjacent the ends of the journals and the various sets of rolls for supporting and driving the shuttle are so spaced as to cooperate with these flanges in holding the shuttle against axial movement. When the shuttle is lowered into the machine as by a crane or the like, it is necessary to axially position the shuttle while on the supporting pads and lift rollers so that when it is lowered onto the support rollers it will be in the proper position. This is accomplished by providing the shaft 67 which supports the rollers 54 with extensions upon which spacers 68, Figure 7, are adjustably mounted and positioned to engage the inside of the flange but of such diameter that they do not engage the journal portions of the shuttle.

This eliminates the necessity for any axial

shifting or adjusting of the shuttle when it is lowered onto the support rollers. Since the driving or regulating wheels are directly opposite the axis of rotation of the shuttle, and since they serve to hold the shuttle in position it will be obvious that if these wheels are not true circles that they will cause the ground surface to be out of round. Means have, therefore, been provided for truing or shaping these wheels while in position, and this means comprises a pair of grinding wheels **69**, Figure 3, attached to opposite ends of a shaft **70** journaled in a housing **71**. This shaft has a drive pulley **72** which is connected by a belt **73** to a pulley **74** attached to the armature shaft of an electric motor **75**.

These parts are all mounted on a slide **76** which may be adjusted toward and from the regulating wheels by a hand wheel **77** shown in Figure 2. The slide **76** is in turn supported upon a longitudinally movable slide **78** which may be moved by a hand wheel **79**. The grinding wheels may be trued by truing diamonds **80** which are adjustably mounted on the housing **81** which supports the shaft for the regulating wheels. Thus the regulating wheels **32** may be trued in situ.

The slide **13** which carries the grinding wheel is operated and controlled by a hydraulic transmission which is diagrammatically illustrated in Figure 8.

The transmission comprises a cylinder **82** which is attached to the underside of the slide **13** and a piston **83** which has piston rods **84** and **85** extending through opposite ends of the cylinder and connected to the bed of the machine. Since the cylinder is the moving member, the fluid pressure is conducted to opposite ends thereof through the piston rod.

The opposite ends of the cylinder are connected to a reversing valve **86** which has a pressure port **87** that is supplied from a pump **88** that draws fluid from a reservoir **89**. A pair of motor ports **90** and **91** in the reversing valve are connected by channels **92** and **93** to opposite ends of the cylinder, these lines extending through a start and stop valve which is indicated in sections in Figure 8.

The sections **94** and **95** of the start and stop valve control the alternate connections of lines **92** and **93** either to the cylinder in the start position, or to the lines **96** and **97** in the stop position of the valve, the latter lines being connected to a hand servo-valve indicated generally by the reference numeral **98**. In other words, when the valve plunger **99** is in the stop position shown, the hand servo-valve is connected to the cylinder whereby the movement of slide **13** may be manually effected and when the plunger **99** is rotated counterclockwise to a start position the manual servo-valve is disconnected and the reversing valve is connected to the cylinder **82**.

The reversing valve **86** has a plunger **100** which is hydraulically positioned in either one of two positions by a pilot valve **101**. This valve has a pressure port **102** and a pair of ports **103** and **104** which are respectively connected to opposite ends of the reversing valve through tarry valves **105** and **106** respectively.

The pilot valve plunger **107** is operatively connected to a trip control rod **108** located on the front of the bed as shown in Figure 1 and adapted to be fired by suitably formed dogs **109** and **110** mounted on the slide **13**. The rod may also be operated manually by means of the handle **111** formed integral therewith.

The reversing valve has a pair of ports **112** and **113** which are connected by channels **114** and **115** to ports **116** and **117** of the pilot valve **101**. When the pilot valve shifts, it serves to alternately connect these ports to a return port **118** whereby the fluid may flow through channel **119** and rate valve **120** to a return line **121**, terminating in reservoir **89**. Thus, the rate of movement of the slide **13** is controlled by throttling the exhaust fluid from either end of the cylinder **82**.

The pilot valve has an enlarged spool **122** which is movable relative to the pressure port **102** whereby after the spool passes the center position the fluid pressure will act to complete the shifting of the plunger and thus act as a detenting mechanism.

The channels **123** and **124** which connect the tarry valves **105** and **106** to the ports **125** and **126** in the opposite ends of the reversing valve for shifting the plunger thereof have serially arranged check valves **127** therein which block the return flow from one end of the valve when the other end is under pressure and thereby cause the opening of by-pass valves **128** which are connected in parallel with the check valves **127** whereby, when the by-pass valves **128** open, the respective line is connected to the return line **121** and thereby by-pass the tarry valve.

The by-pass valves **128** are normally held closed by springs **129** plus the pressure in the supply lines to the tarry valves, but when port **103** or port **104** is connected to exhaust, the pressure is relieved which makes it easier for the valves to open. These valves open to permit a free escape of fluid to the return line rather than being forced back through a tarry valve.

It will now be evident that the table may be started and stopped by rotation of the valve plunger **99** which as shown in Figure 1 is provided with an operating lever **130**, thus affording manual operation of the valve. While the table is in motion it may be automatically reversed by properly setting trip dogs **109** and **110** which operate in conjunction with the trip plunger **108**. Also, on the front of the machine are the control knobs **131**, **132** and **133** which are utilized for adjusting the setting of the tarry and rate valves. When the lever **130** is thrown to a stop position the motor channels are automatically connected to the servo-control valve **98** whereby manual servo-control of the table is obtainable at all times while the table is stopped.

The cross slide **16'** has a depending nut **134** in which is threaded a cross feed screw **135**, Figure 2, which is operatively connected by gearing **136** to a shaft **137** having a hand wheel **138**, Figure 1. By rotation of the hand wheel the cross slide may be manually adjusted. The hand wheel **138** has a finely toothed periphery which is engageable by a pick feed pawl **139** which is oscillated by a piston **140**, Figure 8, slidably mounted in a cylinder **141**. The piston has arcuate notches **142** formed therein which are interconnected by a ridge **143**. A lever **144** is pivotally mounted on a pin **145** in such position that a roller **145** will engage the notches **142**. As the piston is reciprocated the roller rides over the ridge **146** and thereby rocks the lever **144** and this lever is operatively connected to impart an oscillatory motion to the pick feed pawl **139** and thereby produce small infeed movements of the grinding wheel.

The piston **140** is actuated at each reversal of the table and therefore suitable connections are made whereby when the table is reversed the pis-

ton 140 is actuated. This is accomplished by connecting the ports 103 and 104 of the table pilot valve to branch lines 147 and 148 which lead to ports 149 and 150 of the table selector valve. When the plunger 99 of this valve is rotated to effect power reciprocation of the table, cross bores 151 and 152 in plunger 99 connect ports 149 and 150 to ports 153 and 154. Lines 155 and 156 extend from these ports to ports 157 and 158 of a pick feed selector valve 159 which has a rotatable plunger 160 and is shown in six sections. This plunger terminates in an operating knob 161 located on the front of the machine as shown in Figure 1. When this valve is rotated clockwise from the position shown, arcuate grooves 161 and 162 connect channels 155 and 156 to channels 163 and 164 which terminate in opposite ends of the cylinder 141. Thus, upon each reversal of the pilot valve the piston 140 is shifted and for each shifting movement, the lever 144 is rocked to cause oscillation of the pick feed pawl.

There may be cases where it is desirable to infeed the grinding wheel without reciprocation of the table, and means are provided whereby this may be done automatically. To this end the channels 163 and 164 are branch connected to ports 165 and 166 of the valve 159, and by means of arcuate grooves 167 and 168 these ports are connected to channels 169 and 170, which lead to a pair of ports 171 and 172 of a pilot valve 173 and also in parallel relation to a pair of ports 174 and 175 of a reversing valve 176.

The valve 176 has a pressure port 177 and the valve 173 has a pressure port 178 and these two pressure ports are connected by a common channel 179 to port 180 of the pick feed selector valve. This port is connectible by an annular groove 181 in plunger 160 to a pressure port 182 which is directly supplied by the pump 88.

The valve 176 has a pair of ports 183 and 184 which are alternately connectible to the pressure port 177 by the valve plunger 185. The port 183 is directly connected by channel 186 to port 187 located in one end of the valve 178 for shifting the plunger 188 thereof in one direction. The port 184 is connected to a port 189 of valve 178 through a throttle valve groove 190 in plunger 160 of the pick feed selector valve. In other words, the plunger 185 is reciprocated to cause reciprocation of the plunger 188 of valve 178, but in order to control the rate of reciprocation the throttle groove 190 is adjusted to control the flow to port 189 and thereby control the rate of movement of plunger 188 in one direction, but when pressure is admitted to port 187 the groove acts as a throttle to control the rate of escape from port 189 to exhaust.

The grooves 191 and 192 in the plunger 185 serve to connect the ports 183 and 184 to exhaust ports 193 and 194 respectively. Between these grooves is an enlarged spool 195 which serves to complete the shifting of the plunger after it passes the pressure port 177 in either direction and this serves as an automatic detent mechanism.

As the plunger 188 shifts it alternately connects the pressure port 178 to ports 171 and 172 to cause actuation of the pick feed plunger and when the plunger has completed its movement the pressure rises in the respective channels and thereby at either port 174 or 175 of valve 176 to shift either plunger 196 or 197 against the resistance of a spring 198 and thereby cause movement of plunger 185 until it has passed the center position at which time the automatic hydraulic detenting action comes into play to complete the shifting movement. This, in turn, automatically reacts to cause another shifting movement of valve plunger 188. Thus, each valve reacts on the other to cause reversal thereof until the desired infeeding movement has been completed at which time the operator assumes control and manually supervises the completion of the grinding operation.

It will thus be apparent that by means of the pick feed selector valve the pick feeding may be placed under control of the table reciprocating mechanism or may be intermittently and automatically effected without reciprocation of the table.

As shown in Figure 8, a suitable rotary reverse control valve 199 having an operating control lever 200 has connections 201 and 202 to the pump 88 and the reservoir 89 respectively for controlling actuation of the piston 51 in the cylinder 52 which actuates the work shuttle lifting and clamping mechanism. This control may be mounted on the bed as more particularly shown in Figures 1 and 2.

Attention is invited to the fact that when the table start and stop valve is moved to a stop position that pressure and exhaust connections are automatically established with the table servo-motor control valve 98. In other words, the selector valve plunger 99 is provided with a groove 203 for connecting the pressure port 204, which is supplied directly from the pump 88 through channel 205, to a port 206 which is connected by channel 207 to the servo-valve 98.

This serves to effect engagement of the hydraulic clutch which is shown more particularly in Figure 6 and which serves to operatively connect the hand wheel 208, shown in Figures 1 and 2, to the servo-valve 98. As shown in Figure 8 the servo-valve has a pressure groove 209 which is directly connected by a branch 210 to the pump supply line 205. This groove terminates in two pressure ports 211 and 212 in the valve sleeve 213 in which is slidably mounted a pair of valve pistons 214 and 215. This sleeve also has a pair of ports 218 and 219 which are the termini of lines 96 and 97 on the selector valve. There is also a pair of exhaust ports in the sleeve which are connected together to line 220 which leads to the reservoir.

As shown in Figure 5 the servo-valve block 98 has an integral reduced portion 221 by which it is rotatably supported in the housing 222. A pinion 223 is attached to the end of the portion 221 for intermeshing with a rack 224 attached to the underside of the slide 13. This forms a mechanical feed back connection to the servo-valve. The hand wheel 208 is mounted on the end of a shaft 225 which carries a sprocket 226 operatively connected through sprocket chain 227 to a sprocket wheel 228 attached to the shaft 229. As shown in Figure 5 the shaft 229 is operatively connected through a gear 230 and a gear couplet 231 to an internal ring gear 232 formed integral with the clutch member 233. The cooperating clutch member 234 has a plurality of pistons 235 which are urged outwardly by hydraulic pressure into engagement with the flange 236 of the clutch member 233. The clutch member 234 carries a pin 235' which is interposed between the plungers 214 and 215 of the servo-valve. It will be noted that each of the valve plungers 214 and 215 have interdrilling 236' by which the pressure in the annular groove 237 is communicated to the end chamber 238.

This pressure would be the same as the pressure in opposite ends of the table cylinder when the servo-valve is connected for operation and serves to urge or maintain the plungers **214** and **215** into engagement with the intervening pin **235'**. It will now be evident that when the selector valve or start and stop valve is moved to a stop position that hydraulic pressure is provided to effect engagement of the servo-valve clutch whereby the hand wheel **208** is rendered operative and that upon rotation of the hand wheel the servo-valve plungers will be shifted in one direction or the other to admit fluid pressure to one end or the other of the table cylinder while the remaining end is connected to reservoir and that the subsequent movement of the table will cause a feed back connection through the rack and pinion **224**, **223** to effect rotation of the servo-valve block **98** in a direction to follow up the movement of the pin **235'** and thereby recentralize the servo-valve.

An auxiliary grinding attachment has been provided on the wheelhead slide **16'** and comprises an independent slide **239** which is adapted to be moved by a hand wheel **240** through a conventional screw and nut mechanism. This slide has a depending bracket **241** for supporting an auxiliary grinding wheel **242** which may be utilized to grind a groove **243** in the work piece which is more particularly shown in Figure 3. This grinding wheel is mounted on a shaft **244** which is belt and pulley connected to a shaft **245** rotatably mounted in the housing **239**. This shaft is in turn pulley and belt connected to a motor **246** also mounted in the housing **239**. This forms an independent drive for the grinding wheel.

After the cylindrical portion of the work has been ground, the table may be positioned manually as by the servo-motor control mechanism to align the grinding wheel **242** with the groove **243** and then the hand wheel **240** may be rotated to feed the grinding wheel into the work.

If so desired, the usual backrest **247** may be provided for supporting the free end of the work during the grinding operation.

There has thus been provided an improved grinding machine for grinding special work pieces which do not have means for self-support and therefore must be provided with their own special fixtures by which they may be supported for rotation.

What is claimed is:

1. In a machine for grinding cylindrical surfaces on an unsupportable centerless work piece requiring a shuttle having spaced journals for supporting it for rotation, the combination of a bed, means on the bed engageable with the journals for supporting and driving said shuttle to effect rotation thereof about an axis coincident with the axis of the surface to be formed on the work, said supporting means including a pluraility of sets of rollers circumferentially spaced about the axis of said shuttle, said sets of rollers comprising a first set of support rollers and a second set of drive rollers circumferentially positioned to entirely support said shuttle, an additional set of rollers located intermediate said pairs of rollers for lifting the shuttle from the first two pairs of rollers, and means mounted on the bed for receiving said shuttle including a pair of support pads mounted on the bed.

2. In a grinding machine for grinding cylindrical surfaces on centerless work pieces equipped with shuttles whereby they may be supported for rotation, the combination of a grinding wheel supported for axial reciprocation and lateral feeding movement, means for supporting the shuttle for rotation about an axis parallel with the axis of rotation of the grinding wheel, means for initially receiving said shuttle including a pair of rollers, means associated with said rollers for engagement with said shuttle for axially positioning the shuttle with respect to the plane of rotation of the grinding wheel, additional rollers for supporting a rotating shuttle during a grinding operation, and means to actuate the first pair of rollers to transfer the shuttle to said supporting and rotating means.

3. In a grinding machine for grinding cylindrical surfaces on centerless work pieces equipped with shuttles to form rotatable supporting means, the combination of a bed having a grinding wheel supported thereon for rotation and axial reciprocation, the combination of a pair of support rollers mounted on the bed for rotation about an axis parallel to the axis of the grinding wheel, a pair of driving rollers, a pair of clamping rollers for holding the shuttle in engagement with the previous rollers during rotation of the shuttle, a pair of lift rollers mounted on the bed for bodily movement in a direction to lift the shuttle from the support rollers, and power operable means for shifting the clamp rollers and the lift rollers.

4. In a grinding machine for grinding an external cylindrical surface on a work piece equipped with a shuttle for rotatably supporting it with the surface to be ground projecting beyond one end of the shuttle, the combination of a bed, a slide reciprocably mounted on the bed, a hydraulic control circuit in the bed for reciprocating said slide, a wheelhead reciprocably mounted on the slide, means on the bed for rotatably supporting and clamping the shuttle for rotation about an axis parallel to the axis of the grinding wheel, said means including a pair of support rollers mounted on the bed, a pair of driving rollers, power operable means for actuating said rollers and including a start and stop control, means to receive said shuttle upon insertion in the machine including a pair of landing surfaces and a pair of receiving rollers, power operable means for actuating said receiving rollers to transfer the shuttle to the support and driving rollers, a pair of clamping rollers for securing the shuttle against axial or lateral movement during rotation of the shuttle, fluid operable means for shifting the receiving rollers and clamping rollers and a control for causing simultaneous actuation thereof.

5. In a grinding machine, the combination with a bed having means thereon for rotatably supporting a work piece, of a reciprocable slide mounted on the bed for movement parallel to the axis of rotation of the work piece, a cross slide mounted on the reciprocable slide, a grinding wheel supported for rotation on the cross slide, power operable means for actuating the reciprocable slide and feeding the cross slide toward the work to effect a cylindrical grinding operation thereon, an auxiliary slide mounted on the cross slide, a formed grinding wheel supported for rotation on the auxiliary slide, and means to feed the auxiliary slide independent of the cross slide after the cylindrical grinding operation has been completed to effect a formed grinding operation on the work piece.

6. In a grinding machine having a bed and means thereon for rotatably supporting and driv-

ing a work piece, of a grinding wheel, a cross slide for supporting the grinding wheel, power operable means for effecting relative reciprocation between the grinding wheel and the work to effect a reciprocating grinding cycle, and means for effecting an infeeding formed grinding operation on the work including an auxiliary slide mounted on the cross slide, a grinding wheel rotatably mounted on the auxiliary slide, separate power operable means on the auxiliary slide for driving the grinding wheel thereof, and manually operable means to effect infeeding of the auxiliary slide relative to the cross slide.

7. A machine for grinding external cylindrical surfaces on portions of centerless work pieces requiring a supporting shuttle, said work being clamped in the shuttle with the portion to be ground projecting beyond one end thereof, having in combination a bed, longitudinal guideways formed on a portion of said bed, a pair of superimposed slides mounted on said guideways and carrying a grinding wheel, means on one of the slides for driving said grinding wheel, said shuttle having spaced journal portions thereon, means on the bed adjacent said guideway portion engageable with said journal portions for positioning said shuttle to place the work portion to be ground in front of said grinding wheel, power operable means for rotating said shuttle, power operable means for reciprocating said grinding wheel slides and pick feed mechanism for feeding the grinding wheel toward the work.

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