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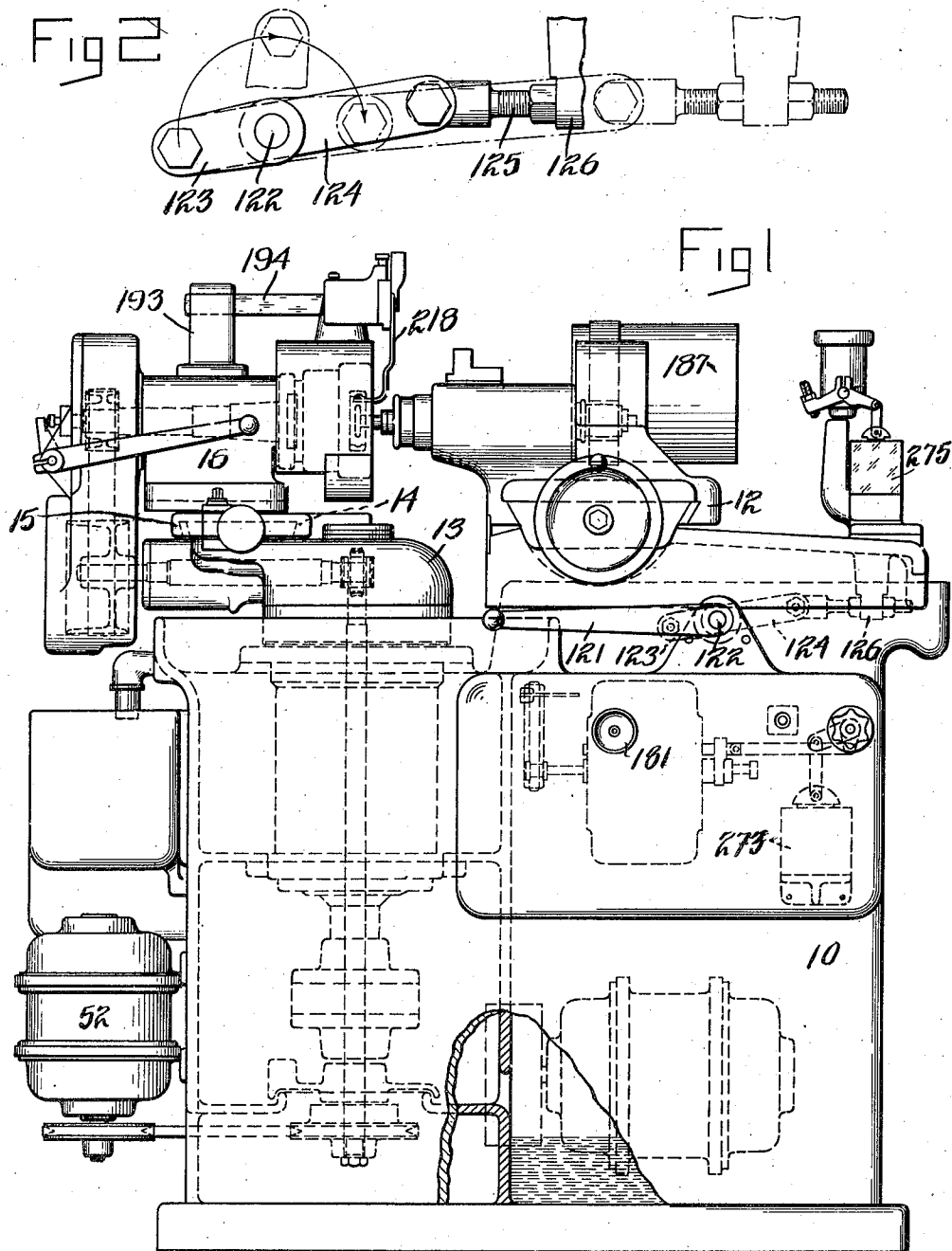
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2,064,427

BALL RACE GRINDER

Filed Aug. 31, 1933

20 Sheets-Sheet 1



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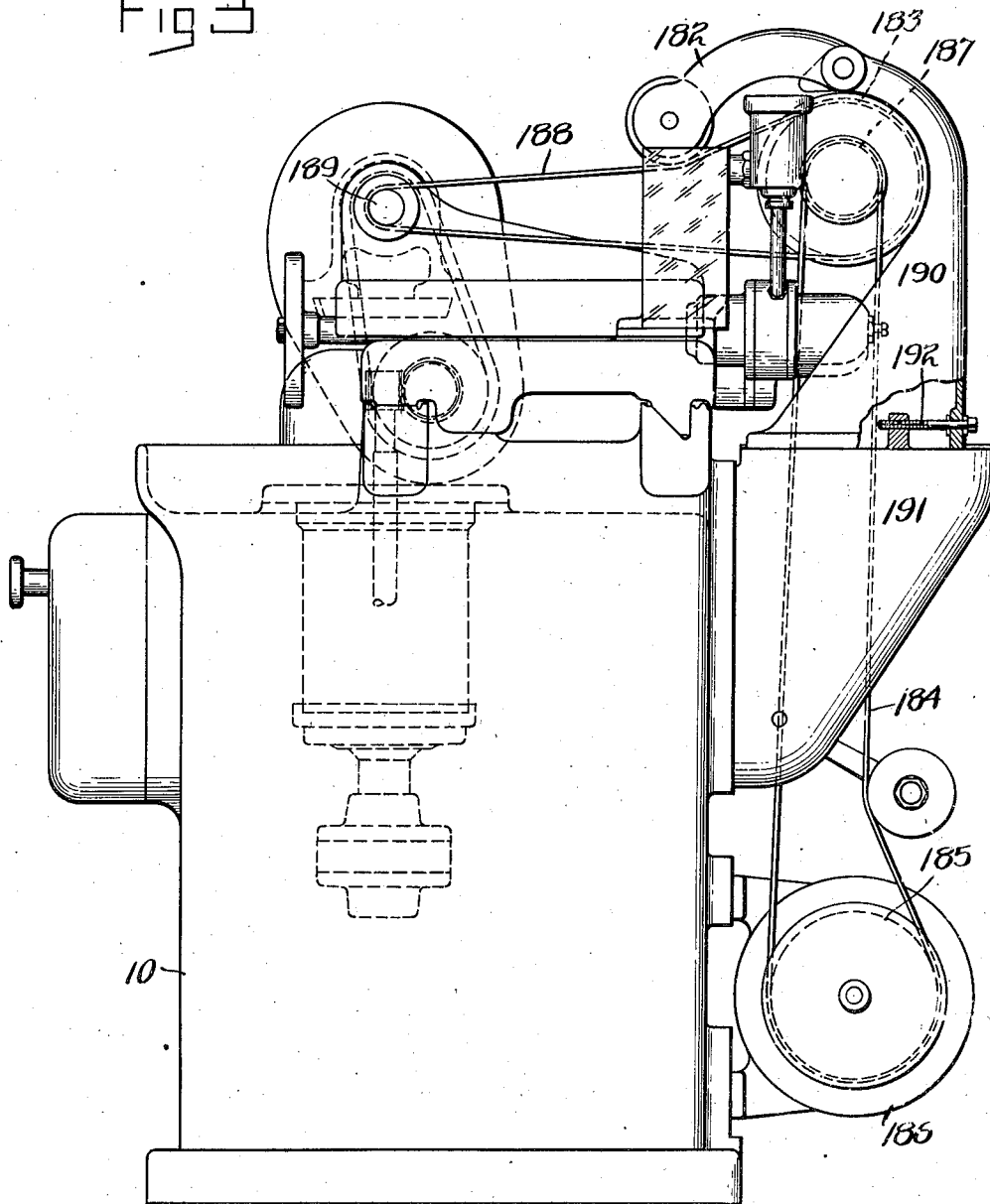
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Fig 3



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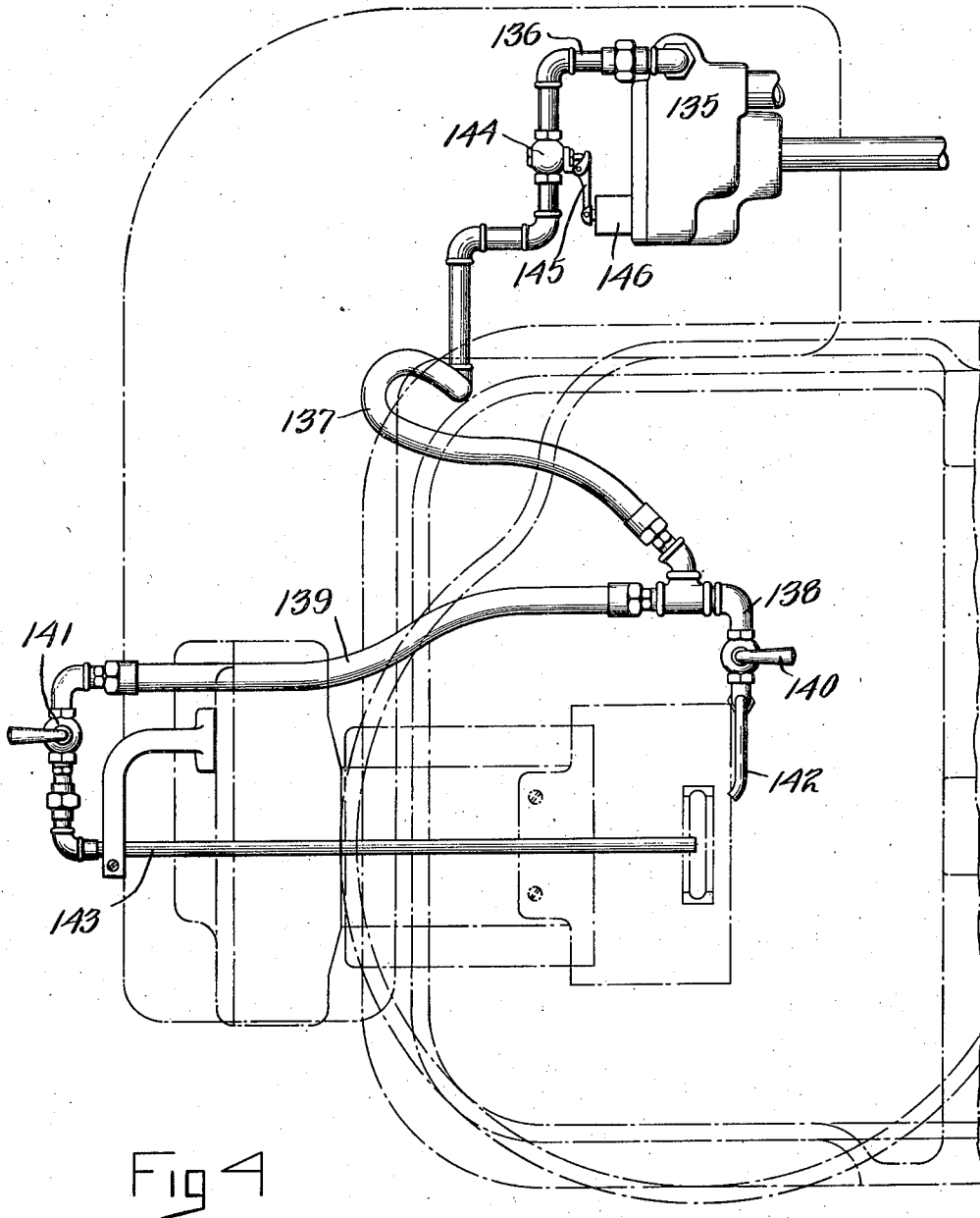


Fig 4

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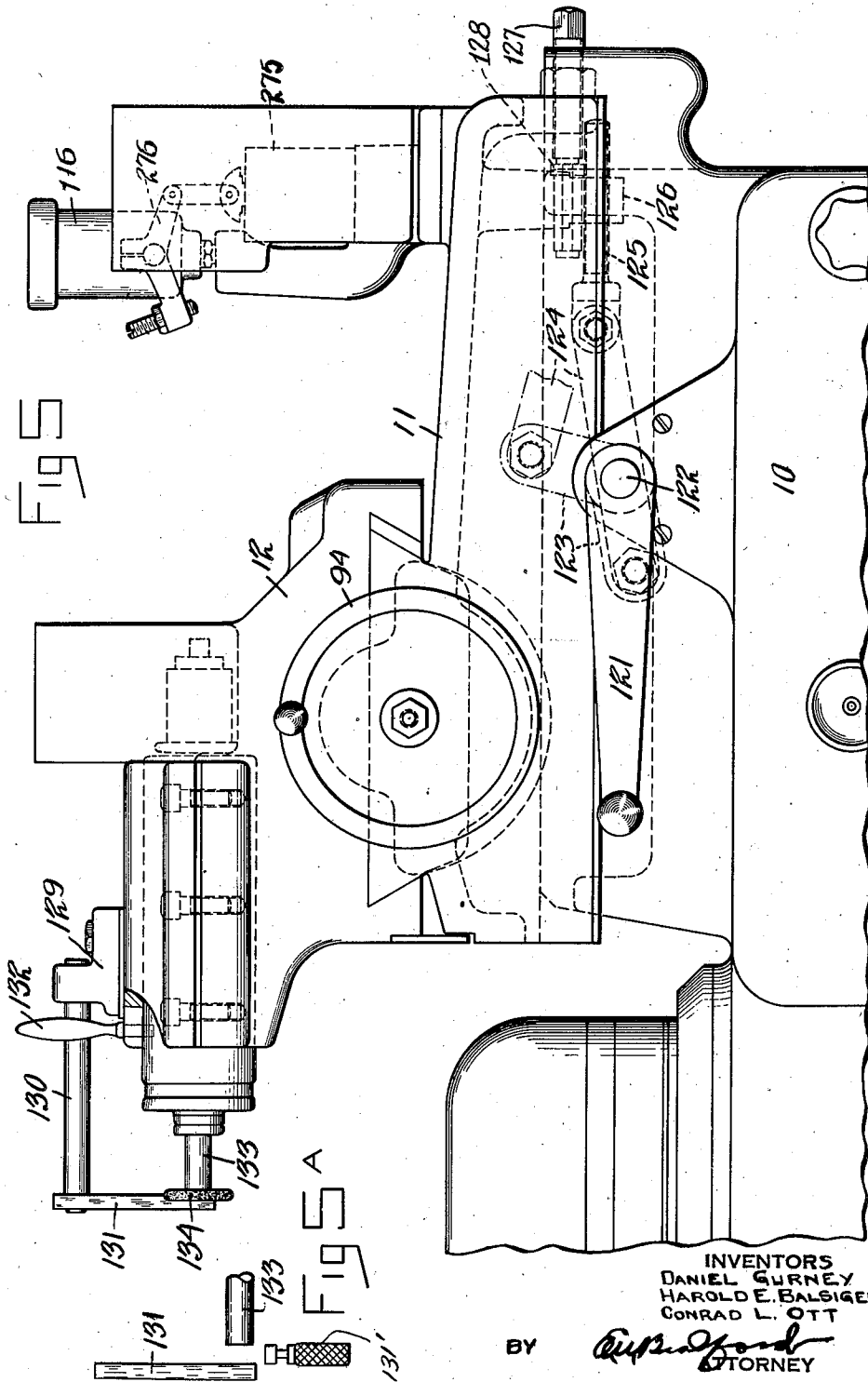
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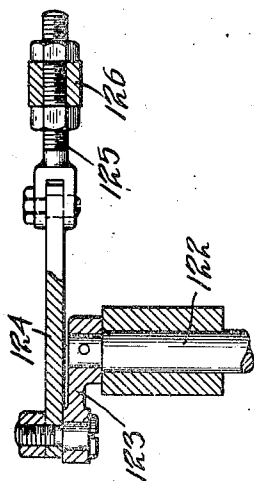


Fig 6A

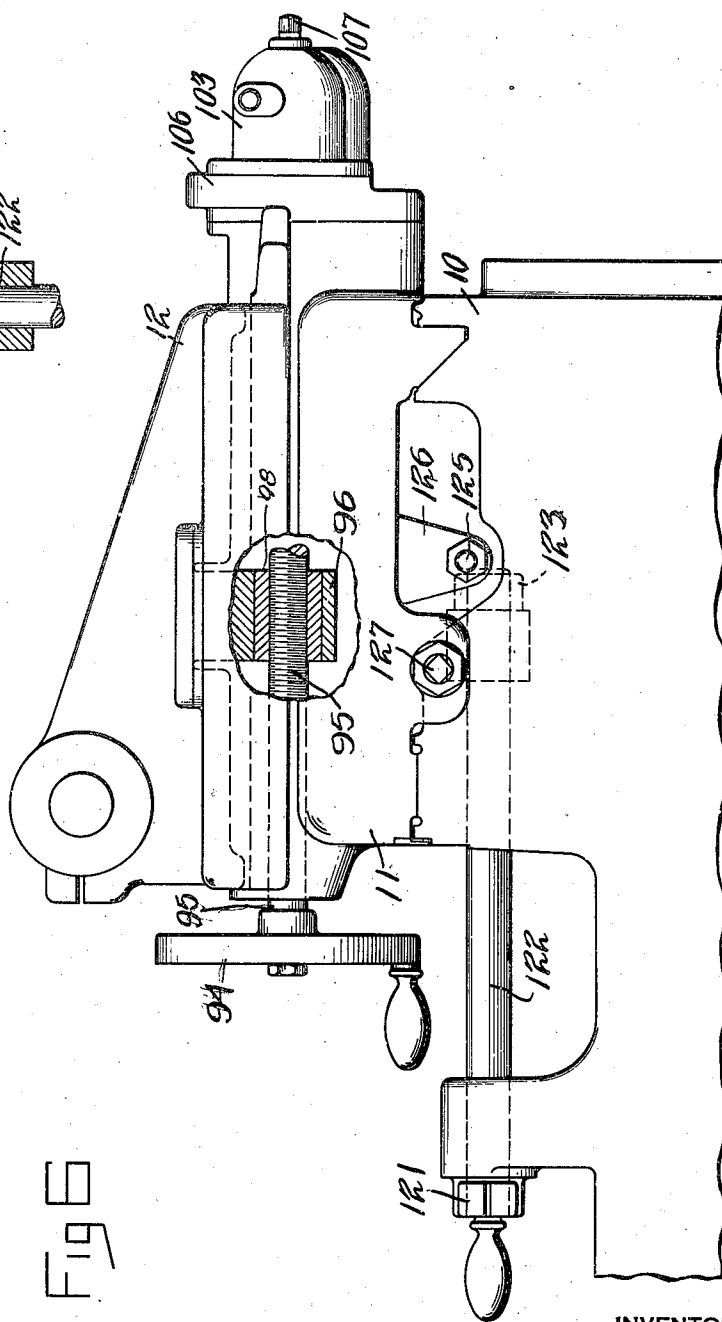


Fig 6

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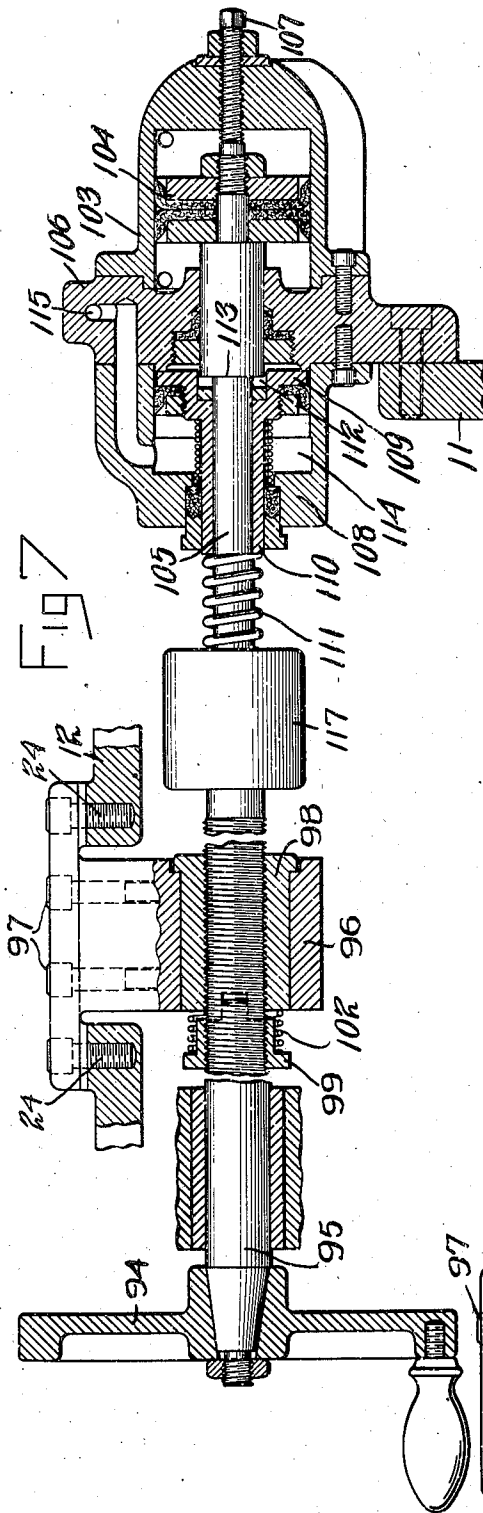
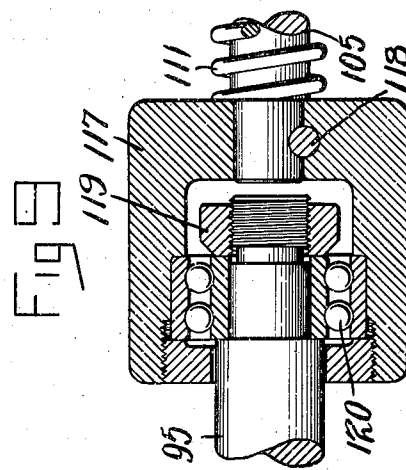


Fig. 8

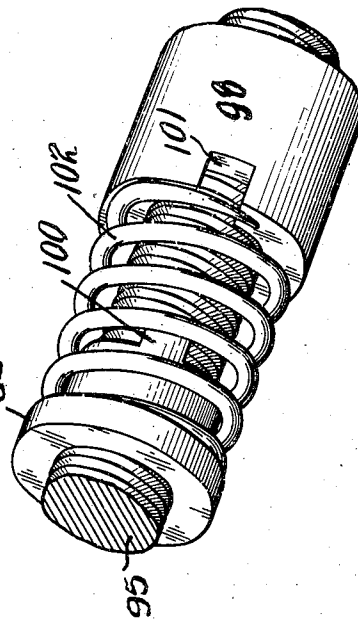
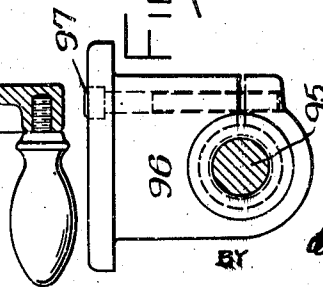


Fig. 9A



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Fig 11

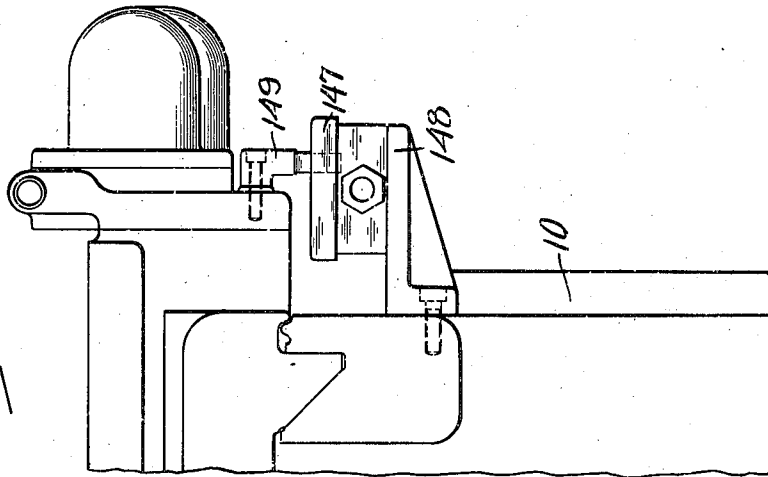
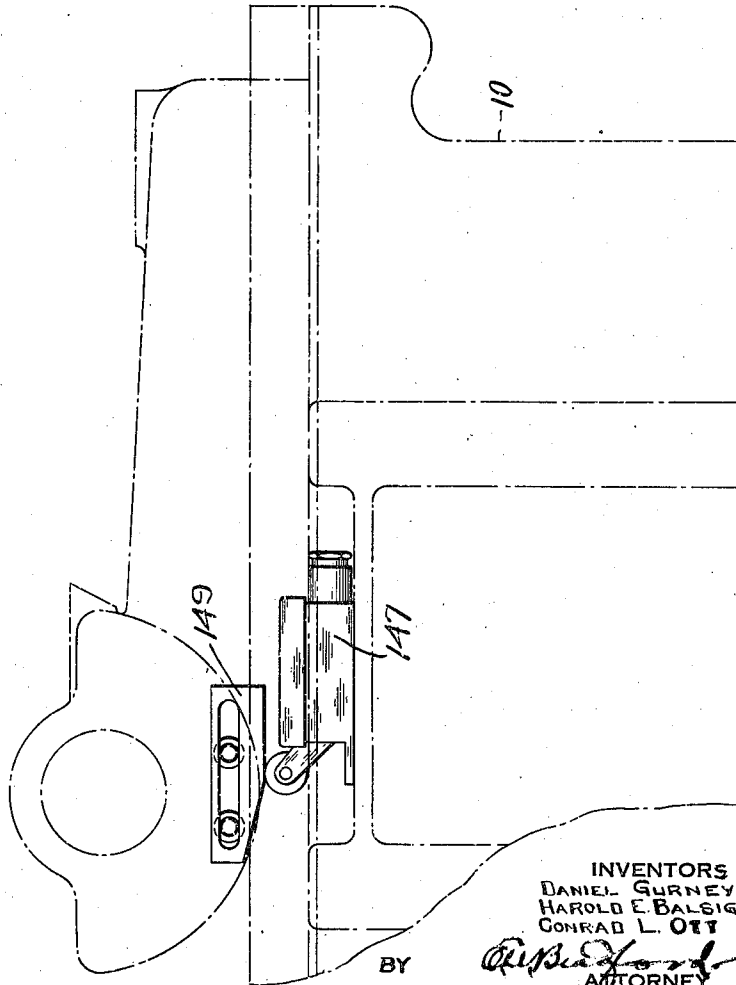


Fig 10



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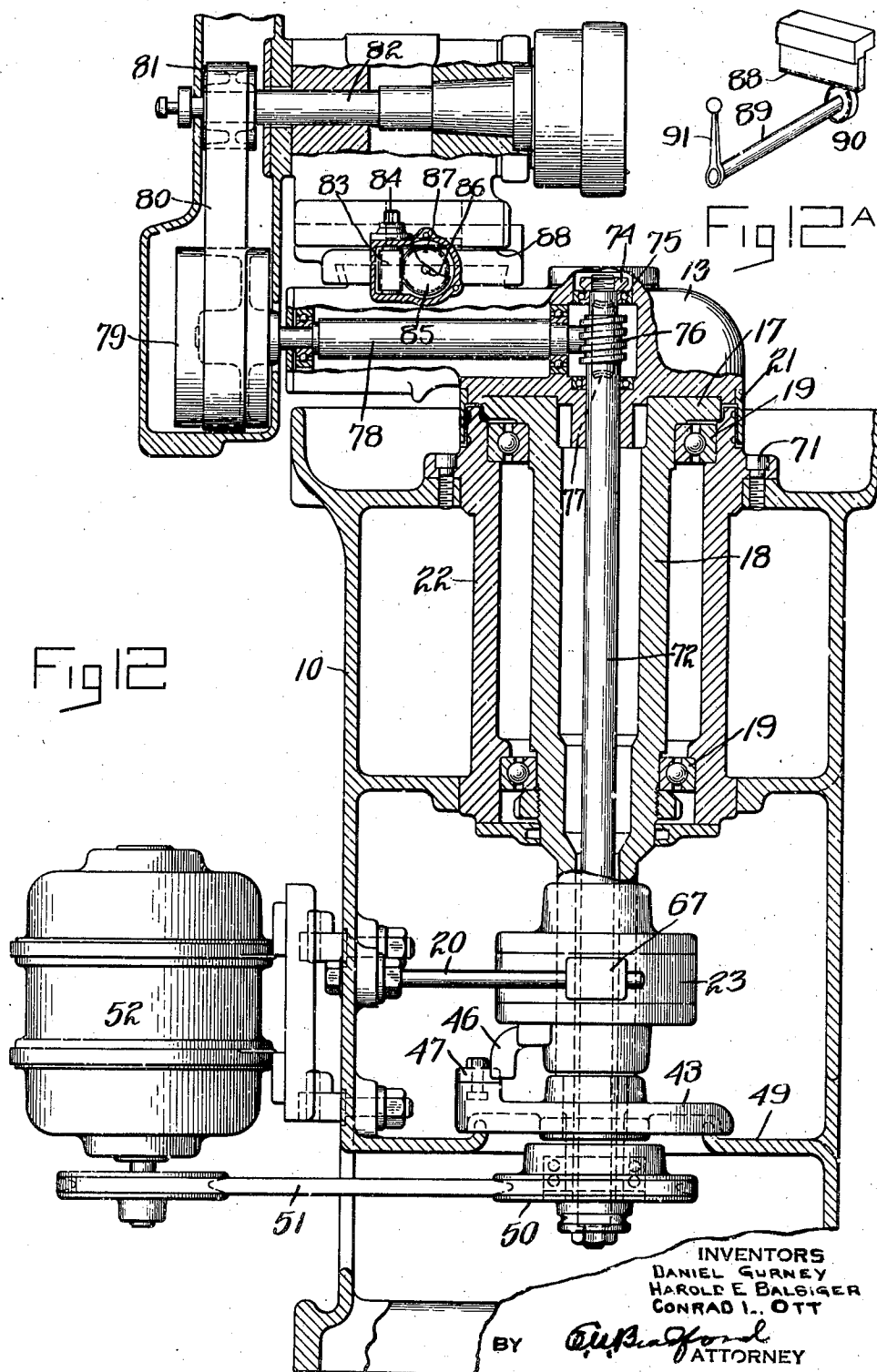
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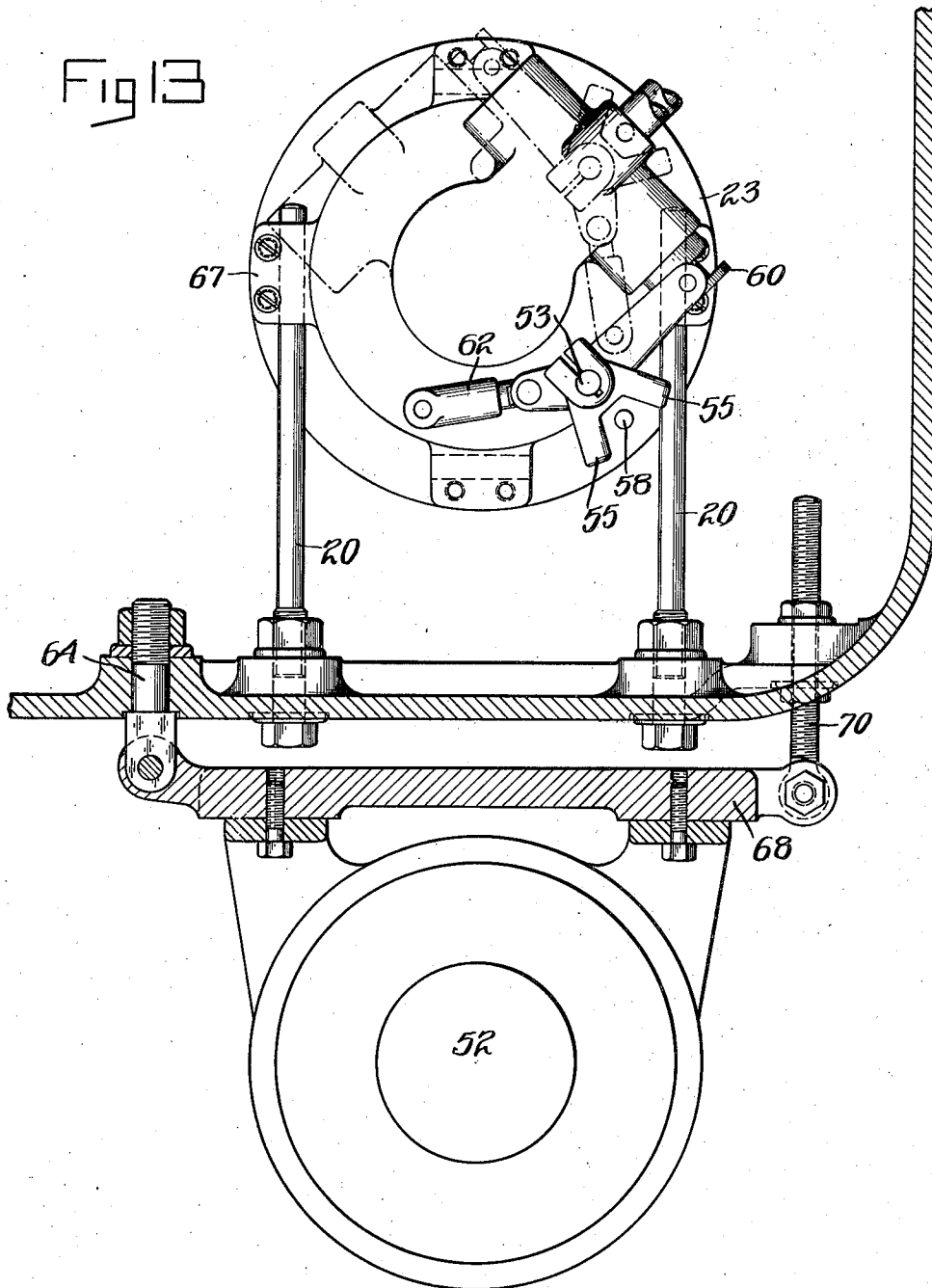
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Fig 13



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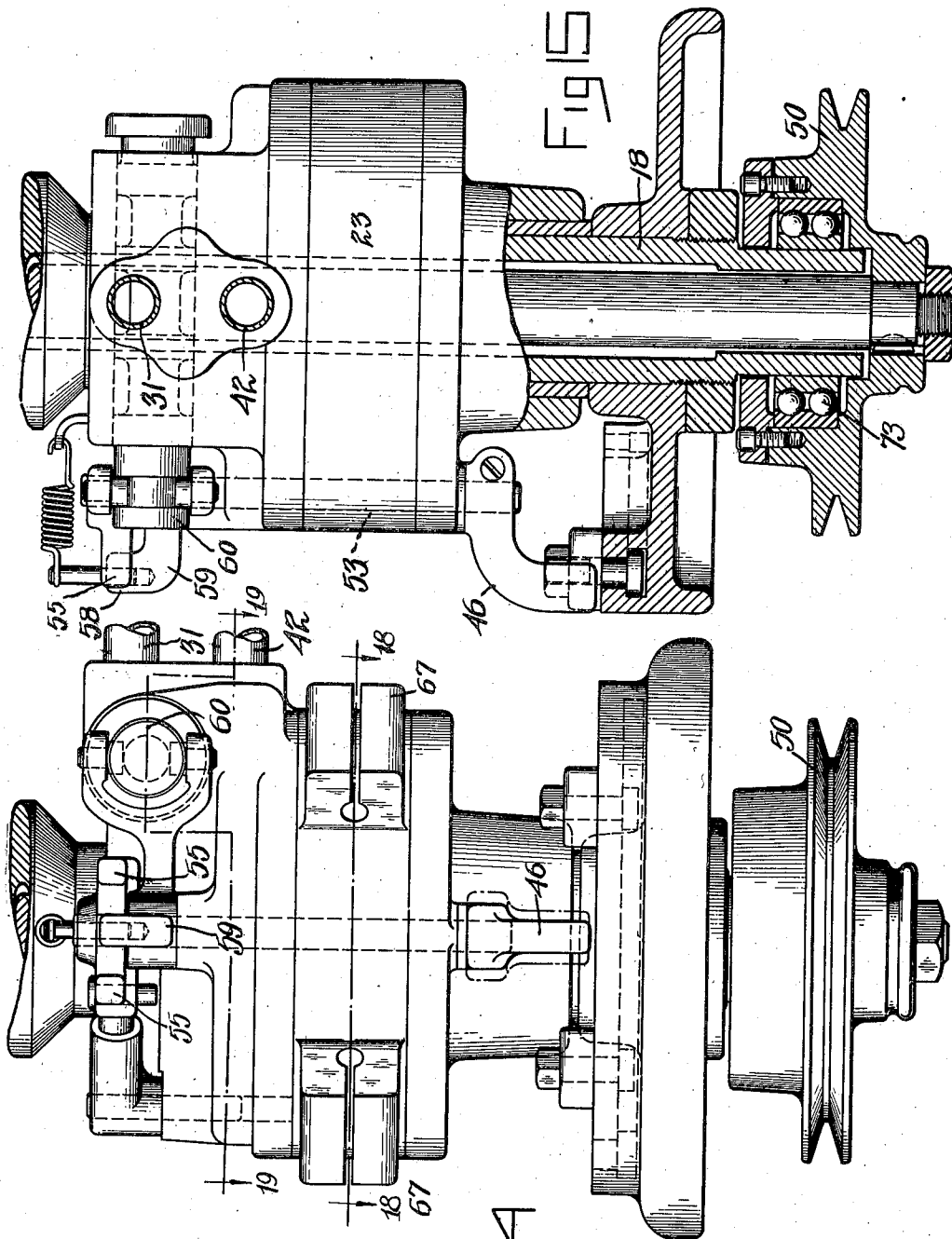


Fig 14

Fig 15

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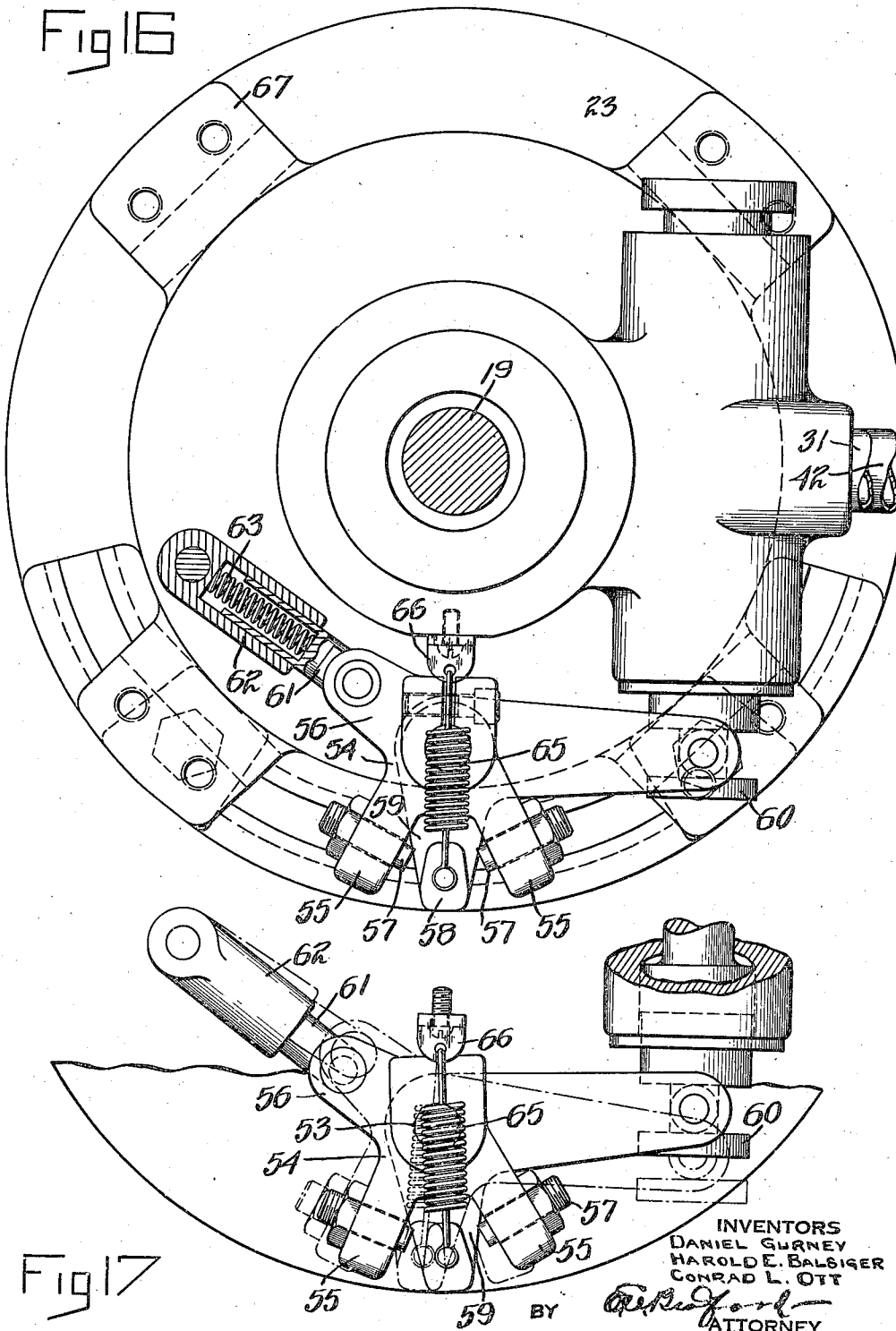
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Fig 16



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Fig 1b

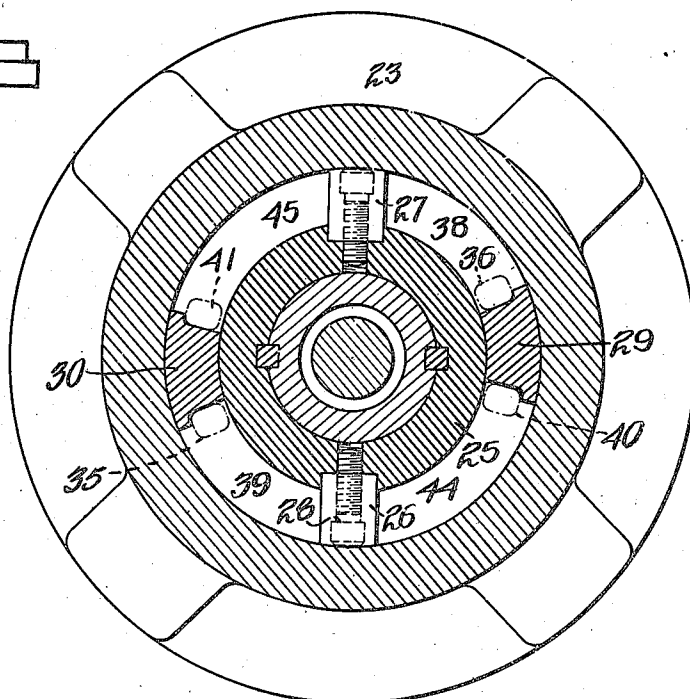
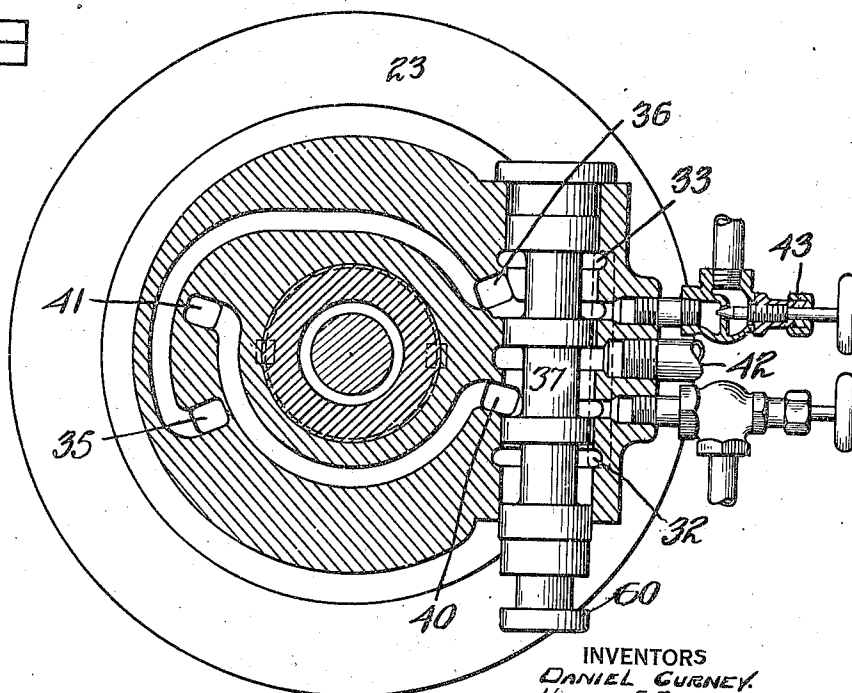


Fig 19



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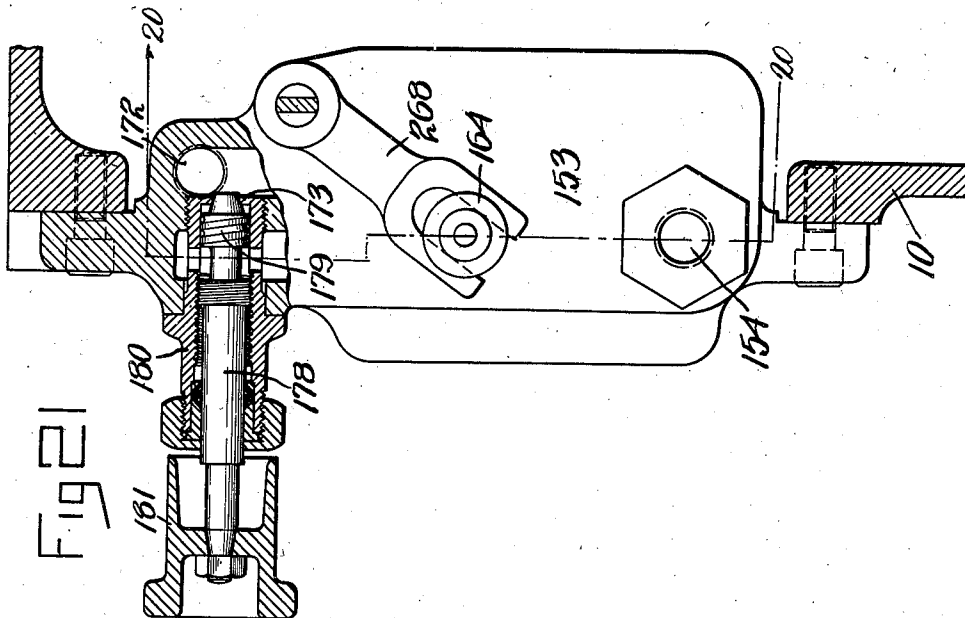


Fig 21

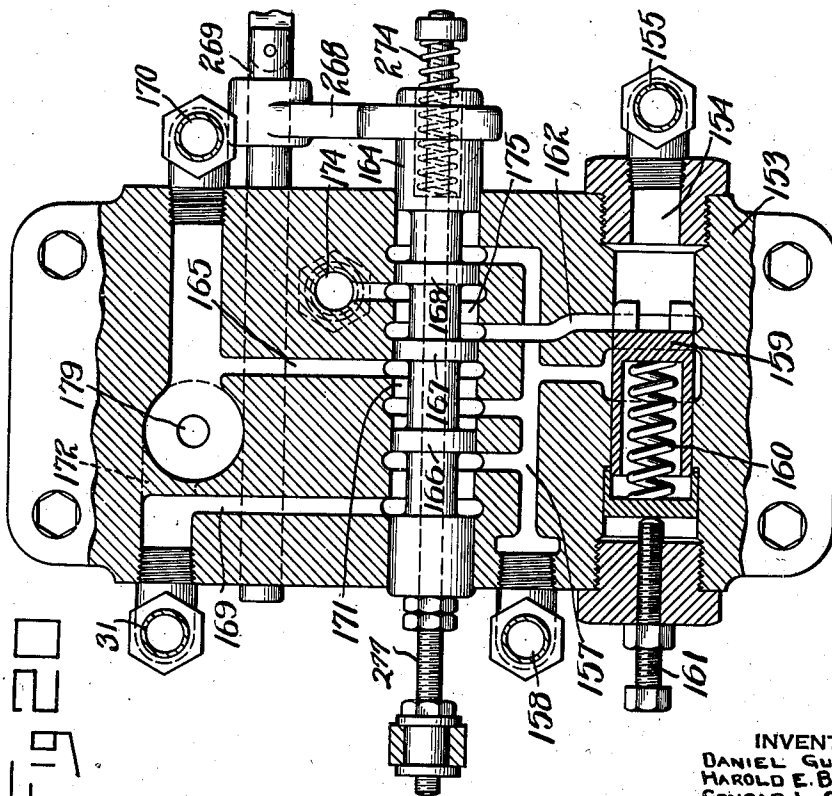


Fig 20

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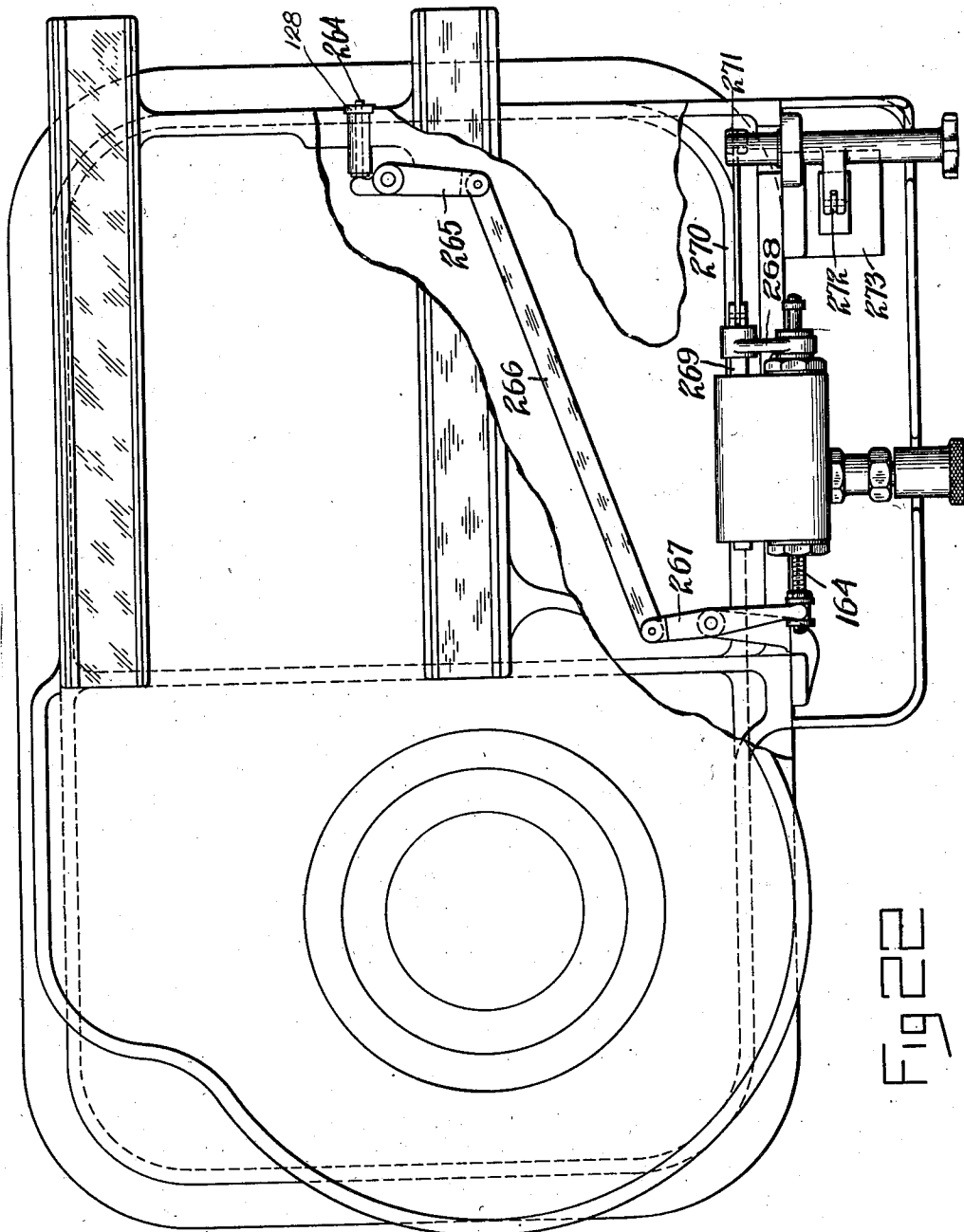


Fig 22

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Fig 24

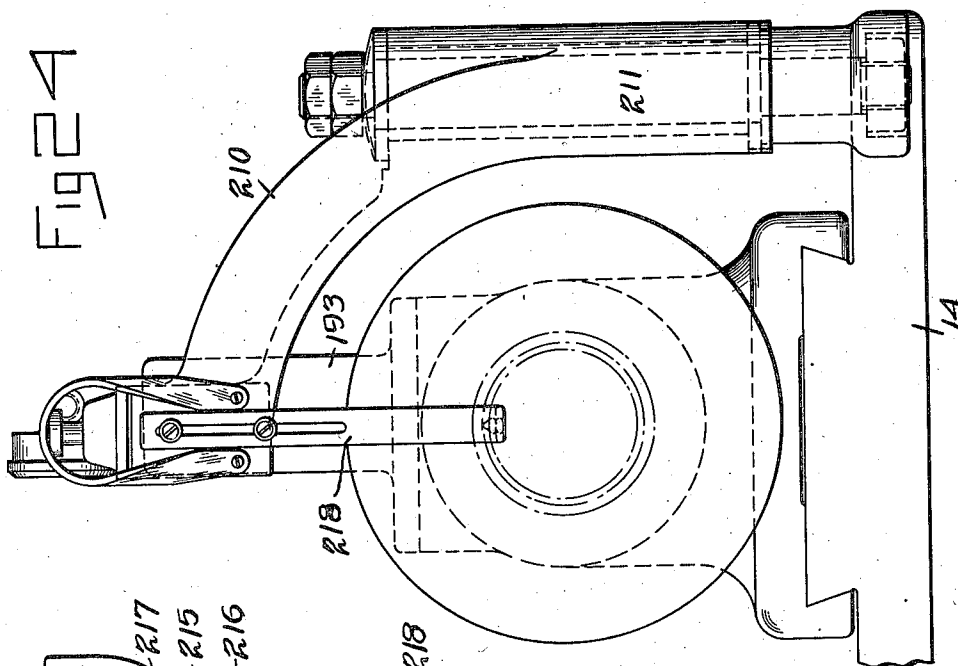
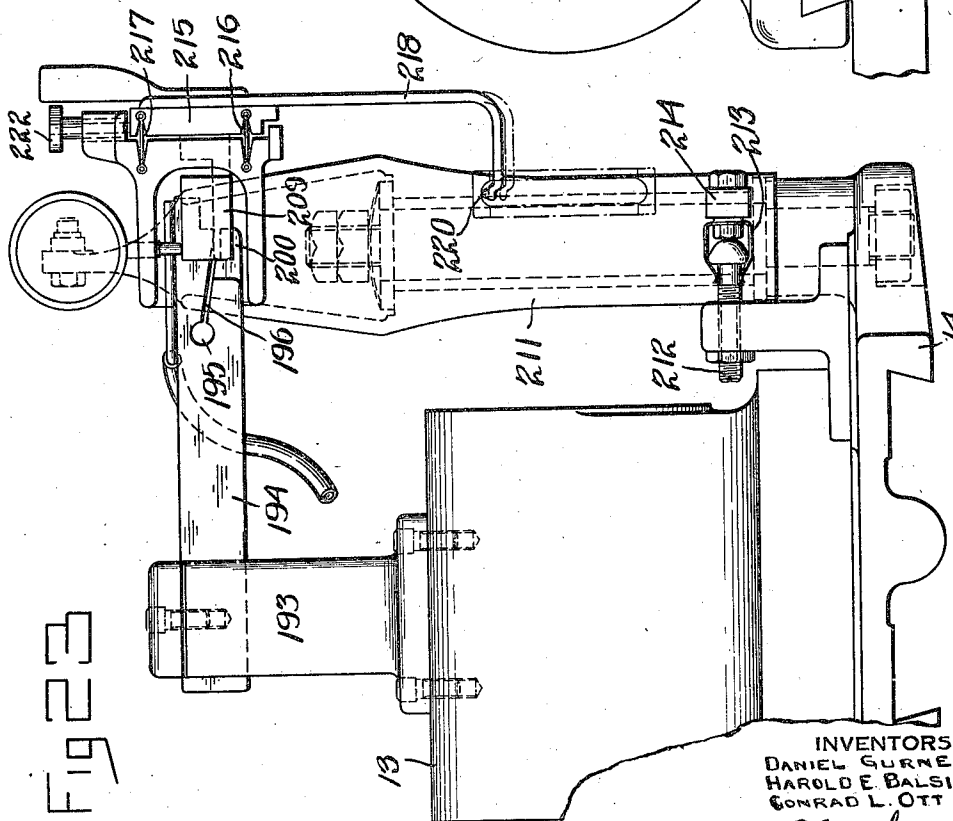


Fig 23



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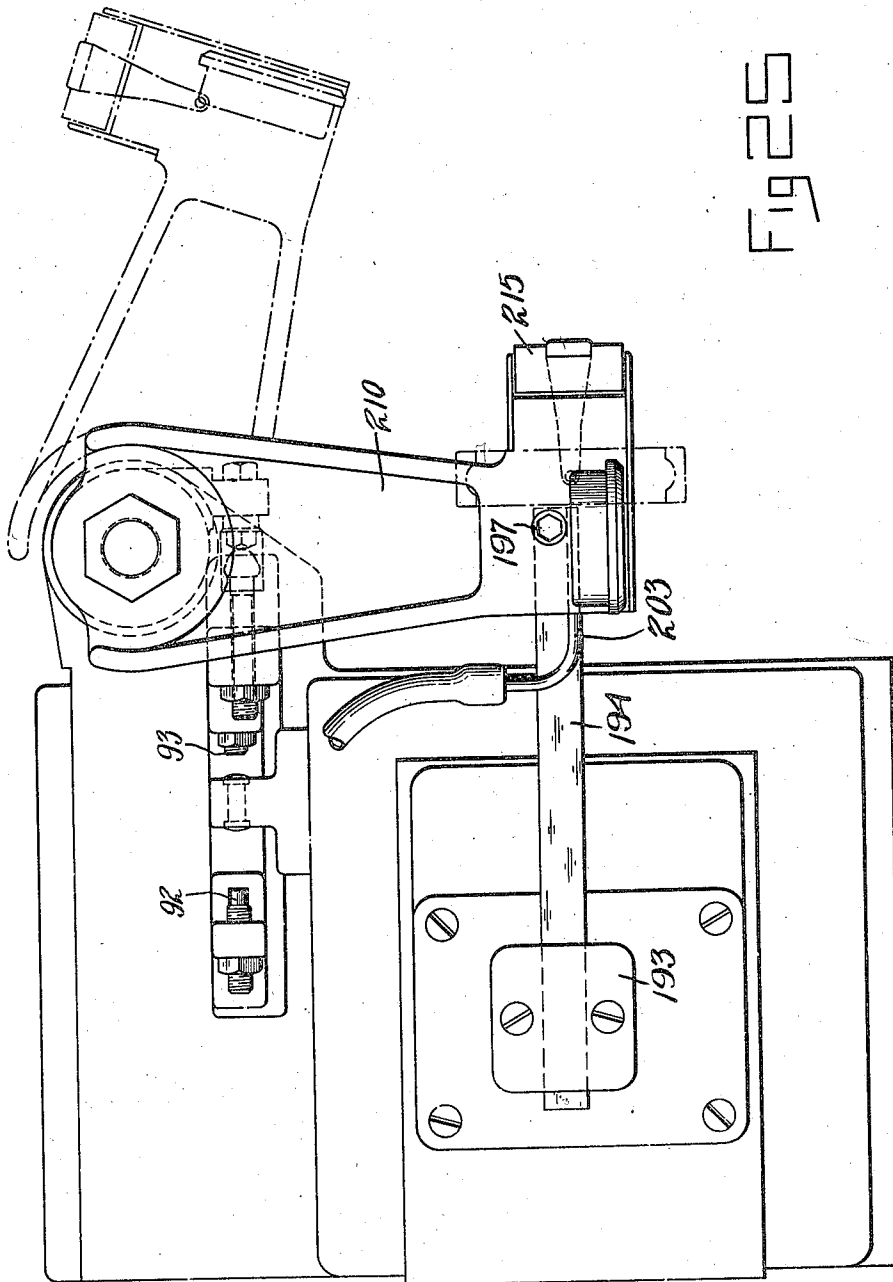


Fig. 25

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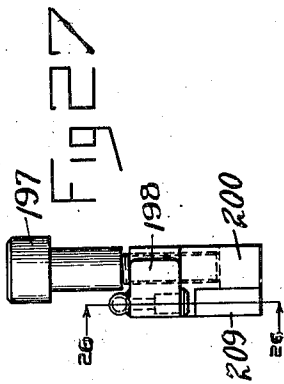
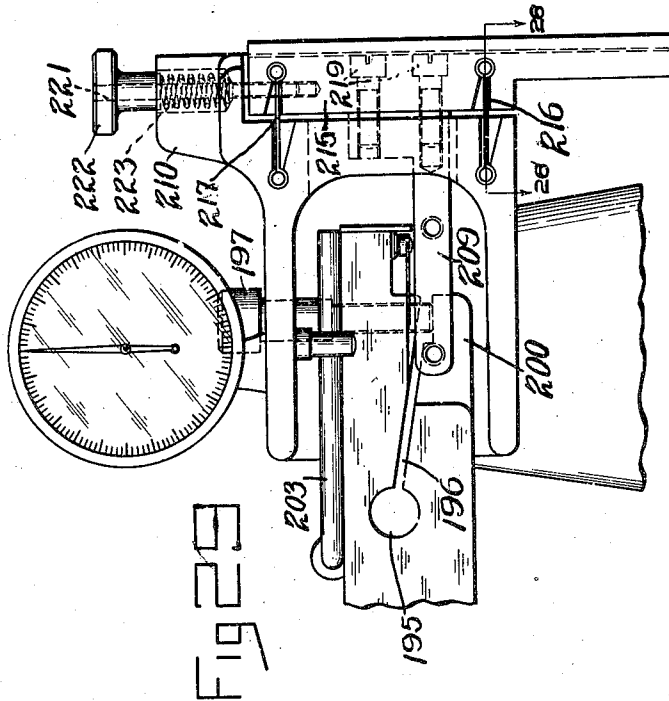
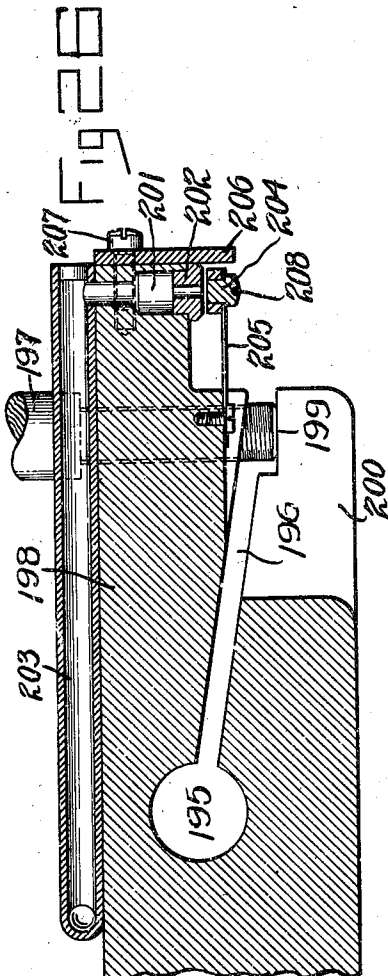
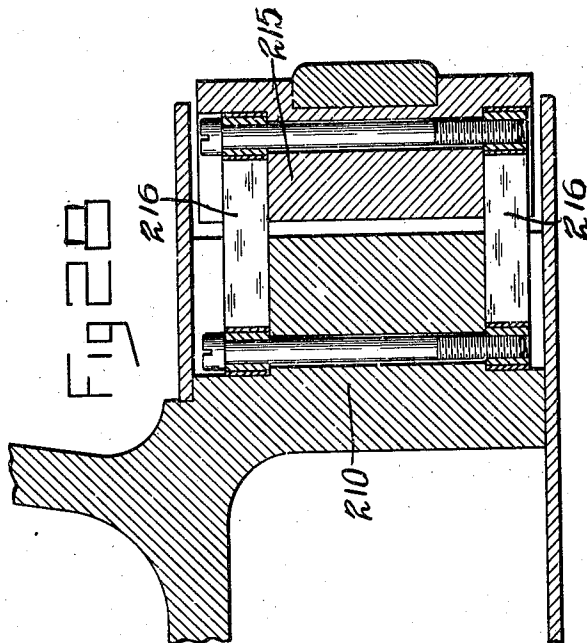
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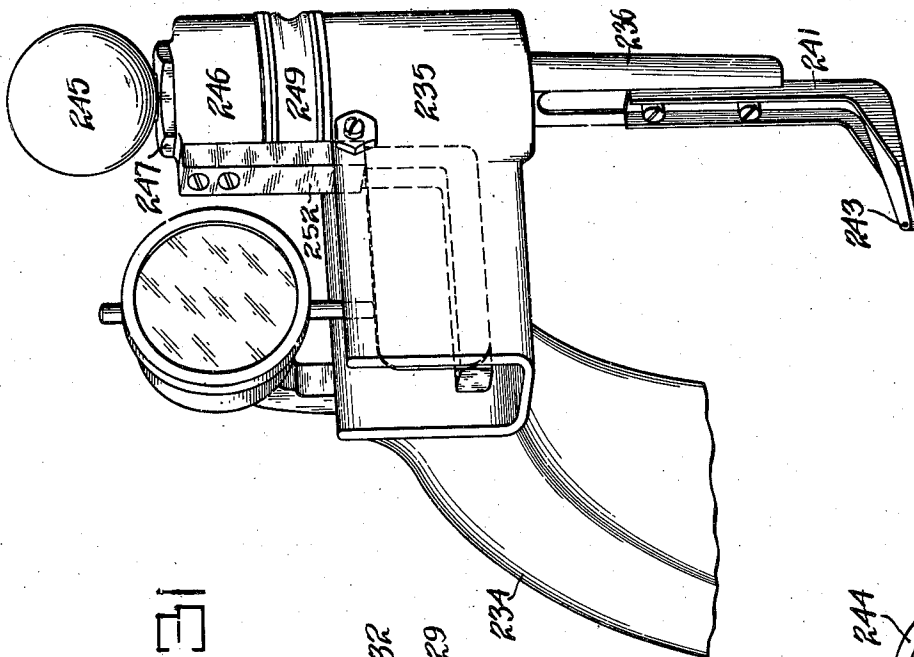


Fig 31

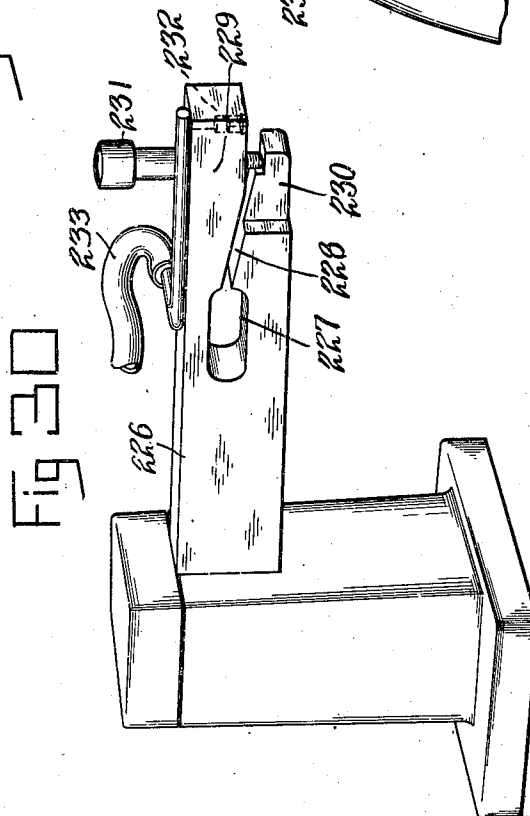


Fig 30

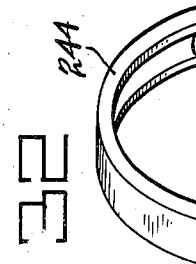


Fig 32

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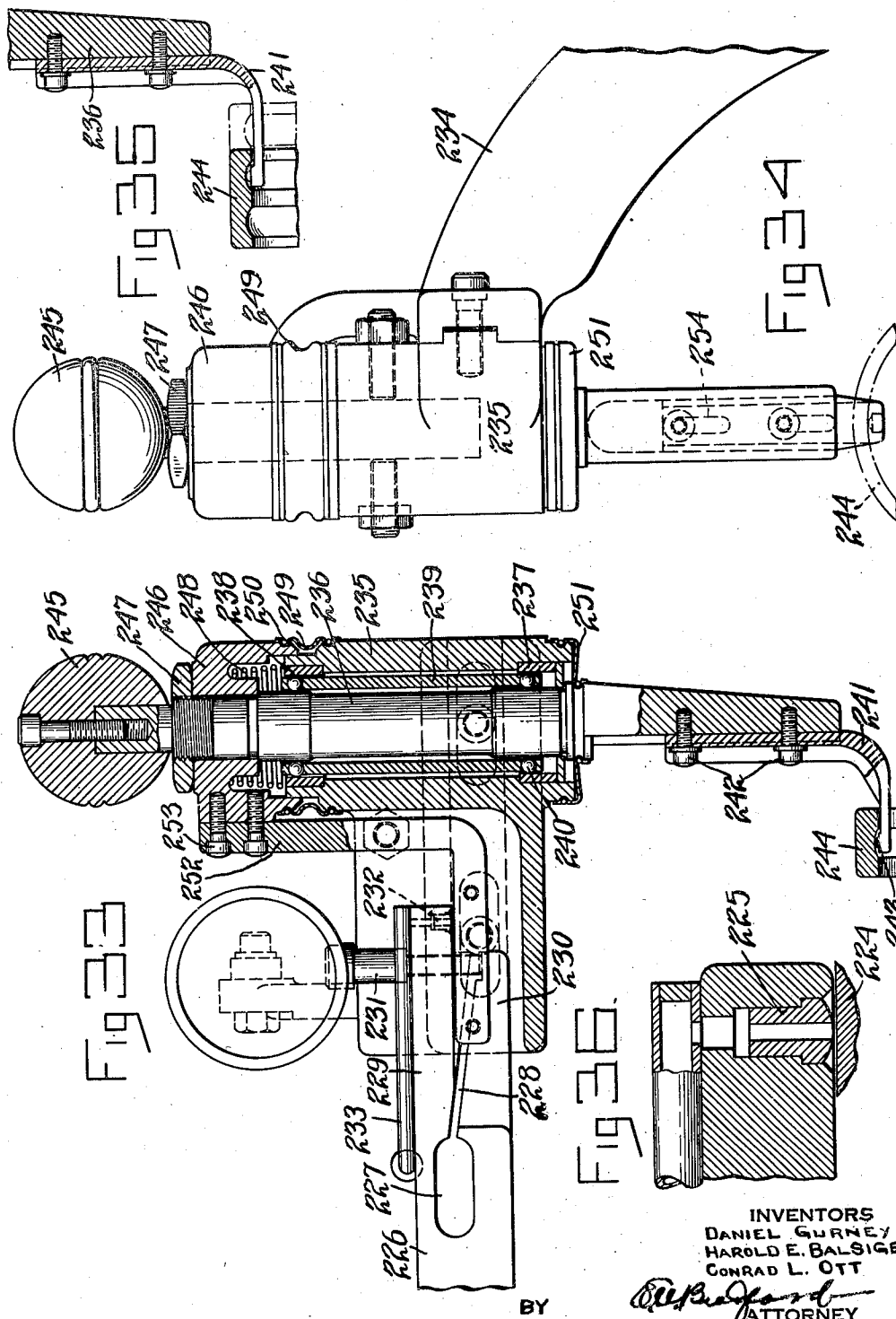
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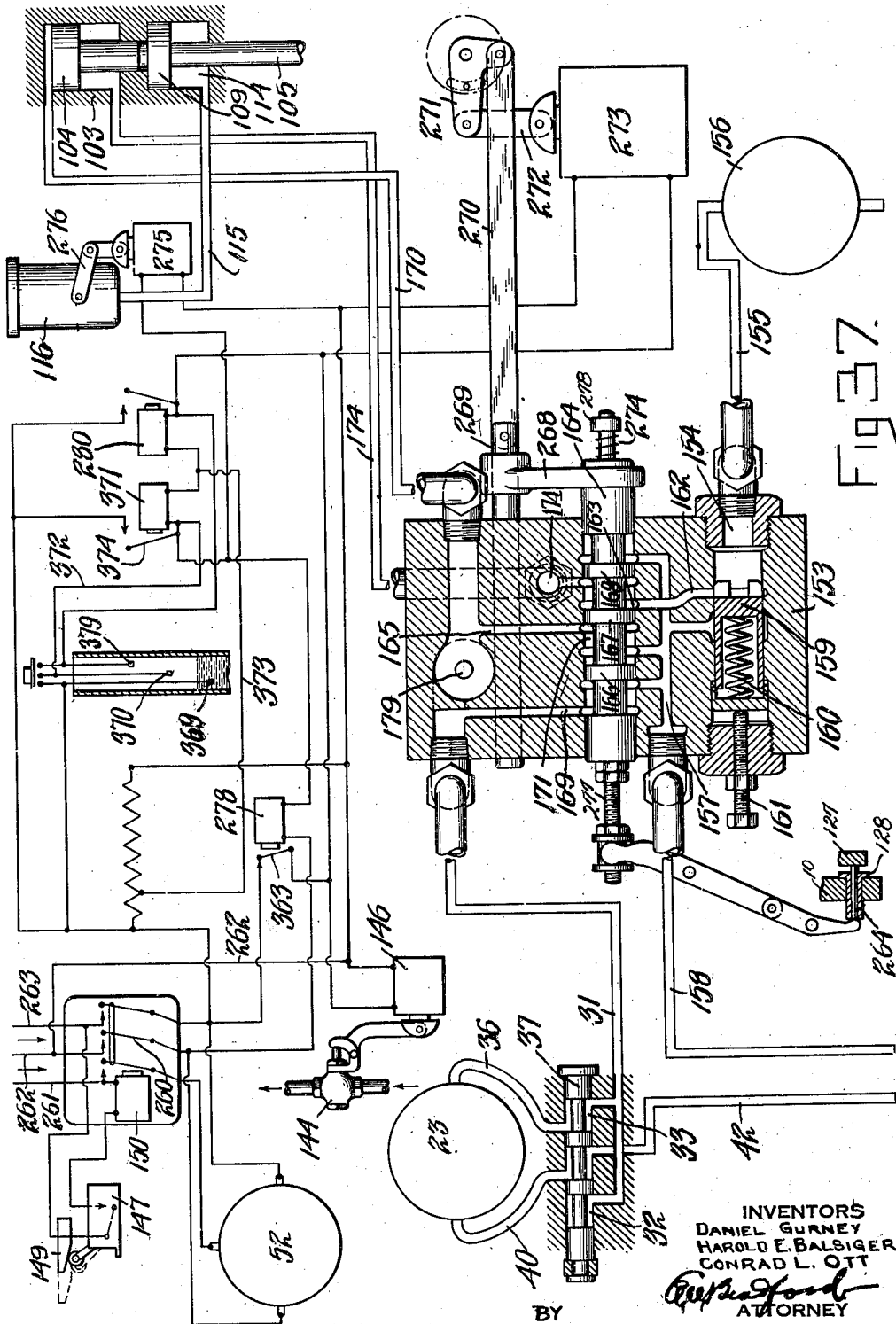
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UNITED STATES PATENT OFFICE

2,064,427

BALL RACE GRINDER

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Application August 31, 1933, Serial No. 687,716

24 Claims. (Cl. 51—97)

This invention relates to machines for grinding ball races and its object is to provide a machine which is partly automatic and partly manually operated.

A further object is to provide a novel method and means for dressing the grinding wheel.

A further object is to provide means whereby the machine may be readily adaptable either for manual or automatic operation without material change of time consuming manipulations of mechanism.

Referring to the accompanying drawings, which are made a part hereof and on which similar reference characters indicate similar parts,

Figure 1 is a front elevation of our machine.

Figure 2 is a partial elevation showing the construction of the manual wheel carriage traverse mechanism.

Figure 3 is a right hand end view showing particularly the method of mounting the driving elements for the wheel spindle.

Figure 4 is a plan view showing the arrangement of the coolant system.

Figure 5 is a front elevation of the wheel base.

Figure 5a is a view showing the method of locating a wheel spindle axially.

Figure 6 is an end elevation of the wheel base.

Figure 6a is a plan view of Figure 2 of the detail of mechanism used in manual traverse of the wheel carriage, partly in section.

Figure 7 is a cross sectional end elevation of the hydraulic wheel feed mechanism.

Figure 7a is a cross sectional view of the mechanism shown in Fig. 7.

Figure 8 is an exaggerated view showing the construction of the split nut type back-lash mechanism.

Figure 9 is a sectional elevation showing the method of forming an operative connection between the feed screw and the piston rod.

Figure 10 is a phantom front elevation of a portion of the machine showing the limit switch on the back of the machine.

Figure 11 is a partial end elevation showing the location of said switch.

Figure 12 is a partial front elevation in section showing the details of the oscillating mechanism for the work support and also the headstock drive.

Figure 12a is a sketch showing a modified form of mechanism for axially adjusting the headstock.

Figure 13 is a plan view partly in section showing the method of mounting the headstock drive

motor and a part of the mounting of the work support oscillating motor.

Figure 14 is an elevation of the oscillating motor looking on the center of oscillation.

Figure 15 is an elevation at right angles to that of Figure 14 partly in section to show the relation between the oscillating spindle and one of the elements of the headstock drive.

Figures 16 and 17 are plan views showing details of the reversing mechanism for the oscillating motor.

Figures 18 and 19 are sections of valve and motor of oscillating motor on lines 18—18 and 19—19, respectively of Figure 14.

Figure 20 is a sectional front elevation of the main control valve on line 20—20 of Figure 21.

Figure 21 is an end elevation of said valve partly in section showing the construction of the throttle valve.

Figure 22 is a plan view with the wheel carriage removed and the bed broken away to show a part of the valve operating mechanism.

Figure 23 is a front elevation showing the sizing device mounting.

Figure 24 is an end elevation of the sizing device mounting.

Figure 25 is a plan view of the sizing device mounting showing also the stops for locating the headstock for single or double row races.

Figure 26 is a sectional front elevation of the support arm showing the method of supplying air to the sizing device taken on line 26—26 of Figure 27.

Figure 27 is an end elevation of the structure of Figure 26.

Figure 28 is a section on line 28—28 of Figure 29.

Figure 29 is a front elevation of the sizing device.

Figure 30 is a view of a sizing device showing details of the support with some elements of the sizing device removed to inoperative position.

Figure 31 is a perspective view of the mounting arm and support for feeler finger, etc.

Figure 32 is a detail of a portion of a work piece, Figures 30, 31, and 32 being located in their relative positions when withdrawn to inoperative position.

Figure 33 is a front elevation partly in section showing the construction of the second sizing device.

Figure 34 is an end elevation of said sizing device.

Figure 35 is a sectional elevation showing the

two positions of the work piece to grind each row of a double row race.

Figure 36 is a close up sectional elevation showing details of construction of the nozzle and nozzle mounting on the optional sizing device.

Figure 37 is a combined wiring and piping diagram.

In carrying out the invention there are provided a hydraulically oscillated work head having novel mechanism for driving the work and for oscillating the head, a grinding wheel carriage with a hydraulically operated feed mechanism in addition to a manually operable means for traversing the carriage into and out of grinding position. The oscillation of the work head is controlled by the traverse movement of the work carriage. This carriage also controls rotation of the work, operation of valves for the coolant supply and the hydraulic feed of the wheel toward the work. A pressure fluid sizing device controls many operating elements on the machine including means to regulate the rate of feed to reduce the feed during rough grinding to a finish grinding speed, to cut off the supply of coolant and finally, when the work has been ground to size, to cause the grinding wheel to back away from the work piece and to start the flow of coolant again. The sizing device also stops oscillation of the work ahead. After finish grinding a piece of work the operator manually traverses the wheel axially away from the work and in response to this movement the work drive motor is stopped and the supply of coolant is again cut off.

An important feature of operation is that after the work has been ground to its rough size the flow of coolant is cut off and further grinding is dry which grinding produces the polished finished surface on the work and at the same time the hard friction of the work on the grinding wheel serves to round off the peripheral edges of the wheel to make them conform to the shape of the work and thus in effect dresses the grinding wheel. This avoids the necessity for an extra wheel dressing device on the machine. It is possible that the machine may begin grinding with an abrasive wheel which has only its corners roughly knocked off and after grinding a short time the wheel is formed by the work to the desired peripheral shape.

The machine comprises a bed 10 having a wheel carriage 11 mounted on and movable longitudinally of the bed and a wheel base 12 mounted upon the wheel carriage and movable transversely of the carriage. The work support consists of an oscillating head 13 having slide ways 14 on which a base 15 slides transversely of the head. A work head 16 is adjustable longitudinally of the base 15. Means for oscillating the head and its associated mechanism will now be described. The head 13 is mounted upon a flange 17 on the upper end of an oscillating shaft 18 which shaft is mounted in bearings 19 supported in a housing 22. The upper bearings are protected from dirt and water by a guard 21 which is secured to the head 13, the guard overlapping the upper end of the housing 22 which encloses the oscillating shaft 18. The shaft 18 is operated by a fluid motor 23, the housing of which is secured to the bed of the machine by means of rods 20. A rotor 25 is keyed to the motor shaft 18 and carries vanes 26 and 27 which are secured to the rotor by screws 28. Segments 29 and 30 divide the

motor casing into two pumping chambers. These chambers are on opposite sides of the shaft to provide a balanced motor. This is preferable to the single blade motor because in the multiple blade type the only stresses exerted on the motor shaft are torsional stresses whereas with a single blade type of motor there is also a lateral or bending stress on the shaft. Fluid to the motor chambers is controlled by a valve 37. Fluid is supplied to valve 37 from pipe 31. Pipe 31 divides into branches which enter chambers 32 and 33. With the valve 37 in the position shown in Figure 37 fluid passes from chamber 33 into ports 36 and 35 and into pumping chambers 38 and 39. When valve 37 is moved to the right, chamber 32 is open to ports 40 and 41 and pump chambers 44 and 45 to rotate the rotor in the opposite direction. Exhaust is through line 42 back to reservoir. Needle valves 43 are connected to ports 36 and 40 respectively, in order to reduce the shock due to a rapid reversal by permitting a portion of the fluid to escape through the needle valves and return to a reservoir in the bed of the machine.

The valve 37 is reversed by means of a lever 46 which is engaged by dogs 47 secured in T-slots in a plate 48. This plate is in the form of an inverted disk and is secured to the lower end of the shaft 18 and extends over an upturned inner edge of a flange 49 extending inwardly from the inner side of the bed of the machine. The disk 48 prevents oil from the bearings from dripping upon a pulley 50 and belt 51 which form part of driving connection between a work drive motor 52 and the work spindle which driving connection will be described more in detail later on. The lever 46 is attached to a shaft 53 which extends up through casing of the motor 23 and has a bell crank arm 54 on its upper end having arms 55 and 56. The arms 55 have stop screws 57 extending through them and engageable with a lug 58 on an arm of a bell crank lever 59, the other arm of which engages a spool 60 on the reversing valve 37.

The arm 56 of the bell crank lever has pivotally attached thereto a plunger 61 operating in cylinder 62 the end of which is pivotally attached to the motor casing. The hollow end of the plunger 61 receives the end of a compression spring 63 which tends to urge the plunger outwardly and forms means for snapping the arms 55 and 56 from one extreme to the other to bring the stops 57 to contact the lug 58 to operate the valve. The lug 58 also carries a spring 65, one end of which is secured to a lug 66 fastened on the motor housing. When either of the reversing dogs engages the reversing lever this lever is carried to the limit of its movement in one direction or the other to snap the valve 37 from one extreme to the other to reverse the flow of fluid to the oscillating motor. The rods 20 are secured at one end to the side of the bed 10 of the machine and have their other ends secured in clamps 67 formed on the motor casing. There are two pairs of these clamps so that the motor casing may be secured in either of two adjusted positions. These two positions are for the purpose of grinding two types of races, namely those used in radial bearings and those used for end thrust bearings.

Work drive mechanism

The work spindle is driven by a motor 52 which is secured upon a plate 68 which is pivotally secured to the bed of the machine by ad-

justing screws 70 which permit adjustment of the motor to tension the belt 51. Power is transmitted from the motor through a belt 51 to a pulley 50 secured on the lower end of a shaft 72 which extends up through the interior of the oscillating shaft 18. The pulley 50 is keyed to the lower end of the shaft and ball bearings 73 are positioned between the pulley 50 and the lower end of the oscillating shaft 18. Shaft 72 is suspended by a nut 74 on the upper end of the shaft, the nut being supported by ball bearings 75 as shown in Figure 12. The shaft 72 has a worm 76 engaging with a worm wheel 77 on a shaft 78. The other end of the shaft 78 carries a pulley 79 which transmits power through a belt 80 to a pulley 81 on the work spindle 82. The purpose of the worm and worm gear drive in the work drive mechanism is to minimize the effect of oscillation on the work drive. The effect of the oscillating movement on the work drive is to cause an irregular movement due to the fact that the source of power for the work drive is stationary while the work itself has an oscillating movement. With the work drive motor inoperative the oscillating movement itself has a tendency to cause the work spindle to rock in its bearings. This tendency continues when the work drive motor is in motion so that when the oscillating movement is in the same direction as work rotation the rate of rotation of the work is reduced from the normal rate. When the oscillating movement is opposite to the direction of work rotation the rate of the rotation of the work is above the normal rate. This is especially true in the bevel gear drives disclosed in some of the references where bevel gears are substituted for the worm and worm wheel. The driven gear which of course oscillates with the headstock has a back and forth movement relative to the driving gear in addition to the rotation caused by the driving gear. When the head oscillates in one direction, the driven gear moves with the driving gear and the rate of relative movement between the two is reduced. When the head oscillates in the opposite direction the movement of the driven gear is opposite to that of the driving gear and the rate of relative movement is increased. Obviously, such a combination of movements can not help but be detrimental to the work piece being ground.

By using a worm on the driving shaft and a worm gear on the oscillating driven shaft the oscillating movement causes the worm gear to oscillate about the axis of the worm. The rocking movement of the driven shaft produced by this motion is equal only to the lead of the worm gear on that small portion of the worm over which the worm gear oscillates. The work head 16 is manually adjusted toward and from the work by means of a worm 83 on a shaft 84, the worm engaging a worm wheel 85 on one end of a shaft 86, the other end of the shaft having a pinion 87 engaging the under side of a rack 88 on the work head 16. The end of the shaft 84 is preferably polygonal so as to receive a crank or wrench by means of which the adjustment may be made. The purpose of this adjustment is to locate the work piece directly on the center of oscillation of shaft 18.

Some types of work have double races and for grinding these it is advantageous to have a quick adjustment from one to the other. To provide such adjustment mechanism shown in Figure 12a may be substituted for the precision adjust-

ment just described. In Figure 12a the shaft 89 has a pinion 90 engaging the lower side or rack on the work carriage. The shaft 89 is operated by means of an arm 91. Stops 92 and 93 shown in Fig. 25 determine the two positions of the work carriage for the two races in the work to be ground. It is not necessary to have the fine precision adjustment so that rod 89 is manually rotated by the arm 91 to move the work carriage to either of the two positions in which it will be stopped by the lugs and stops just described. Positioning of the work carriage is accurate and at the same time the adjustment can be quickly made. The housing 22 is secured in flanges on the bed 10 by screws 71. These may be removed and the whole work support and its oscillating and operating elements lifted off the machine.

Wheel feed mechanism

The wheel feed mechanism consists of a hand wheel 94 attached to a feed screw 95. The feed screw is connected to a bracket 96 which is secured to the wheel base by means of screws 24. A portion 98 of a split nut is mounted on the feed screw 95 in the bracket 96. The other portion 99 of the split nut is mounted on the feed screw 95. Tongues 100 on one portion of the split nut engage slots 101 of the other portion, the portions having a spring 102 to urge them apart. This provides a back-lash or mechanism for taking up lost motion in the threads on the feed screw. The wheel is fed by pressure fluid toward the work and is controlled by pressure fluid to limit its feeding speed during grinding. The hydraulic feed of the wheel toward the work is accomplished by means of a feed cylinder 103 and a piston 104. The piston is attached to a piston rod 105 which is connected to screw 95 by coupling 117. The cylinder 103 is secured to a bracket 106 secured to the wheel carriage 11 and an adjusting screw 107 threaded through the rear of the cylinder determines the range of movement of the piston 104. A cylinder 108 is also mounted on the bracket 106 opposite the cylinder 103 and this cylinder carries a piston 109. This piston has a piston rod 110 preferably made integral therewith which piston rod surrounds the piston rod 105. The piston 109 and the cylinder 108 function as a feed regulator. A spring 111 surrounding the piston rod 105 bears against the end of piston 110 and holds it against the side of the bracket 106. The piston 109 has a recess 112 which receives the enlarged portion 113 of the piston rod 105. There is a certain amount of lost motion between the enlarged portion on piston rod 105 and the piston 109 to allow for a rapid feed of the grinding wheel before the wheel contacts with the work. The enlarged portion 113 on piston rod 105 may be moved freely through the recess 112 until it engages the inner side of the piston 109 after which the piston 109 must also be moved to permit further feeding. The chamber 114 at the left of piston 109 in Figure 7 is filled with oil which is forced out through a port or fluid line 115 and a needle valve into reservoir 116. The opening through the needle valve determines the speed of the wheel during the grinding. Piston rod 105 and feed screw 95 are connected by a coupling 117 shown in section in Figure 9. Piston rod 105 is fixed to the coupling 117 by a key 118. Feed screw 95 is rotatably mounted in ball bearings 120 in the coupling and is held against axial movement in the coupling by means of a nut 119. Bracket 96 is in the form of a clamp and

secures the split nut by clamping screws 97. By removing the screws 24 and screws which hold bracket 106 the feed screw together with the entire feed mechanism may be removed from the machine.

In Figures 2, 5, and 6 mechanism is shown for manually traversing the wheel carriage toward and from the work. This mechanism consists of a crank 121 secured to a shaft 122 which extends forward through the front of the bed of the machine. The rear end of the shaft has attached thereto an arm 123 to which is connected a link 124. This link is connected to a pin 125 which is secured to a bracket 126 which depends from the rear end of the wheel carriage. The arm 123 and the link 124 form a toggle. When the crank 121 is turned to the left the wheel carriage is brought into working position and when it is turned to the right the carriage is moved to inoperative position. As the carriage moves into operative position an adjustable stop 127 engages a fixed stop 128 to locate the carriage in proper grinding position. The lever 121 may be moved a short distance after the carriage stops so as to move the arm 123 past dead center as shown in Figure 2 and thus lock the carriage in grinding position. This provides a single lever for operating the wheel carriage and for locking it in grinding position. Mounted upon the wheel carriage is a gauge bracket 129 from which extends a bar 130, this bar having a depending arm 131 for use in locating the grinding wheel in correct position. A handle 132 on the housing of the grinding wheel shaft 133 serves to shift the spindle axially to locate the grinding wheel 134 in correct position.

The bar 130 with its depending arm 131 is mounted in a fixed position so that the inside surface of said arm is in axial alignment with the axis of oscillation. The line passing through the center of the grinding wheel must coincide with the axis of oscillation and therefore must also coincide with the inside surface of arm 131. The grinding wheel is mounted on the end of spindle 133 so that the end of said spindle must be located half the width of the grinding wheel from the center of oscillation. In order to properly locate the spindle in this position a gauge 131' is used. This gauge has a portion which is equal to half the width of the grinding wheel that is to be used and the spindle is located with its end spaced from the inner surface of arm 131 a distance equal to the width of gauge 131'.

Coolant for the grinding wheel is supplied by a pump 135 delivering through a pipe 136 and a flexible connection 137. The delivery line divides into two lines 138 and 139 which are controlled by cut-off valves 140 and 141. A nozzle 142 is positioned adjacent the front of the work and the pipe 139 is connected to a pipe 143 which is mounted so as to extend through the work spindle and terminate within the work so as to supply coolant upon the grinding wheel both at the front and rear of the work. Flow of coolant is controlled by a valve 144 which is operated automatically by a lever 145 which is operated by a solenoid 146. The solenoid may be actuated by a limit switch 147 or by sizing device. The valve may also be operated directly by some moving part of the machine. As shown in Figures 10 and 11 a bracket 148 is mounted on the rear of the bed of the machine. The limit switch 147 is supported by this bracket and is operated by a cam 149 on the wheel carriage. As the wheel carriage moves

in to grinding position cam 149 depresses an arm on the limit switch and closes circuit through a solenoid 150. Through other circuits which will later be described, the solenoid 146 is energized to open the valve 144. The limit switch 147 also controls the work drive motor 52.

The hydraulically operated devices of the machine are controlled by a single control valve shown in sectional detail in Figures 20 and 37. This control valve consists of a valve body 153. Fluid is supplied to the inlet port 154 through a pipe 155 from a pump 156. An outlet port 157 is connected by a pipe 158 to a reservoir in the bed of the machine. A pressure responsive relief valve 159 under the tension of a spring 160 holds the valve 159 closed but permits it to yield under pressure to bypass fluid directly from port 154 to exhaust port 157 and a screw 161 is provided for adjusting the tension of the spring 160 so as to permit the relief valve to yield at any predetermined pressure. Fluid passes through a port 162 into a chamber 163 controlled by a valve 164 having valve disks 166, 167, 168, which control each of several ports 25 through the valve. The valve 164, as shown in Figure 37 is in extreme right-hand position. When in this position fluid line 31 through which the work head oscillating motor 23 is operated is connected through port 169 to exhaust port 157. Line 170 from rear of wheel feed cylinder is also open through port 165 and chamber 171 to exhaust port 157. Pipe 174 through which fluid is directed to the front of the cylinder 103 is connected to the supply port 163. With valve 164 in the left-hand position fluid passes from port 162 to port 165 through valve 179 and port 172 to pipe 31 to the work oscillating motor and thru passage 170 to the rear of cylinder 103. With the valve 164 in the extreme right-hand position as shown in Figure 37 all parts of the machine are in inoperative position or are moving to inoperative position. The valve 179 consists of a valve stem 178 which is threaded with a sleeve 180 and having an operating knob 181 on its end.

The mechanism for operating valve 164 consists of a pin 264 slidably mounted in fixed stop 128. Said pin is slightly longer than the stop and is adapted to protrude so that it may be engaged by the adjustable stop 127 on the wheel carriage. The other end of said pin engages one end of lever 265. The other end of said lever is connected by means of link 266 to one end of another lever 267. The other end of lever 267 engages or fits in a spool in the end of rod 277. Both the levers 265 and 267 are pivoted at points intermediate the ends thereof. Rod 277 extends through the valve 164. At the right-hand end of said rod which extends beyond the end of said valve is mounted a collar 278. Said valve is bored out at this end to accommodate a spring 274 which is mounted between said collar and the bottom of said bore. An arm 268 connects said valve with a shaft 269 slidably mounted in the valve casting 153 and parallel with said valve. Shaft 269 is connected by means of a link 270, ball crank 271 and another link 272 with solenoid 273.

In the above description it can be seen that valve 164 is adapted to be shifted in one direction by movement of the work carriage and in the other direction by solenoid 273.

A spiral passage 173 is formed about the end

of the valve stem. The spiral forms a restricted passage the length of which may be adjusted by moving the stem axially to increase the amount of friction necessary to be overcome in the passage of fluid through the valve.

The grinding wheel is driven by a motor 186 through a pulley 185 and a belt 184 to a pulley 187 mounted on a jack shaft. Another pulley 183 drives the grinding wheel through a belt 188 and a spindle 189. The jack shaft is mounted on a bracket 190 which bracket is in turn slidably mounted on a support 191. A belt tightener 182 is pivotally mounted to the bracket 190 and carries a roller engageable with the belt 188. Bracket 190 may be adjusted on the support 191 by means of an adjusting screw 192. The support 191 is mounted on the bed of the machine. By virtue of this construction there is no element of the operating mechanism for the grinding wheel mounted on the wheel carriage. Since only the spindle and the pulley on the grinding wheel shaft are mounted on the wheel carriage, the transmission of vibration due to the driving mechanism to the grinding wheel is avoided and results in more accurate work, for any vibration of the periphery of the grinding wheel results in grinding an irregular surface on the work.

Sizing device

Various forms of the sizing device are shown in Figures 23 to 35 inclusive. As shown in Figure 23 a support 193 is mounted on the head stock and carries an arm 194. The outer end of the arm has a hole 195 through it and the end of the arm has a saw slot 196 extending from the hole downwardly to the end of the arm. Screw 197 is threaded through the portion 198 above the slot and engages a surface 199 on the portion 200 below the slot. The purpose of the screw is to adjust the portion 198 which carries one portion of the sizing device relative to a support which carries another portion of the sizing device. The end of the arm 198 has a chamber 201 in which a nozzle 202 is inserted. An air pipe 203 is secured to or mounted on the arm 198 and communicates with the chamber 201. A valve 204 is carried on a spring 205 which is secured to the arm 198. A guard 206 is secured by a screw 207 to the end of the arm 198. The valve 204 preferably carries a hardened point such as a diamond 208 which is engaged by a shut-off arm 209 as will presently appear.

Other elements of the sizing device consist of an arm 210 which is pivotally mounted on a post 211 carried by the adjustable base 15. The arm 210 is located and held in position by an adjustable latch 212, a latch spring 213 and a stop 214, as best shown in Figure 23. The arm 210 carries a block 215 resiliently mounted thereon by means of springs 216 and 217. The finger 218 is securely attached to the block 215. The shut-off arm 209 which engages the valve 204 is also secured to the block 215 by means of screws 219.

The finger 218 carries a hardened point such as a diamond 220 which is positioned to engage the surface of the work which is being sized. A knob 222 carries a pin 221 which is secured to the block 215. A spring 223 is mounted in a hole in the arm 210 and engages beneath the knob 222, the spring tending to urge the block 215 to its uppermost position. By depressing the knob 222 the diamond 220 is moved out of contact with the work to permit the feeler finger to

be swung away from the work, the arm 210 being swung around on its pivot 211 to idle position.

In the form of the device shown in Figure 36 the arm 224 which corresponds to the arm 209 in Figure 23 engages the nozzle 225 directly so as to dispense with the additional valve element 204 shown in Figure 26.

In Figures 30 to 35 is shown a slightly different form of sizing device illustrating the same general inventive principle. This form of the device has a supporting arm 226 which has an oblong slot 227 and a saw slot 228 dividing the end of the arm into upper and lower portions 229 and 230. A screw 231 is threaded through the upper portion and engages a surface on the lower portion 230. A nozzle 232 is fitted in a hole in the end of the portion 229 and an air pipe 233 connects with the nozzle. An arm 234 is pivotally mounted upon the base 15 and this arm has a cylindrical portion 235. A shaft 236 is mounted and adapted to move vertically within the cylindrical portion 235. The mounting consists of a special type of ball bearing which consists of outer races 237 and 238. A tube 239 is positioned between the shaft 236 and the interior of the cylindrical portion 235, this tube carrying ball bearings 240 and serving to hold them in place, the balls providing a bearing between the shaft 236 and the elements 238 and 239. The shaft 236 itself forms inner race for the bearings. A feeler finger 241 is attached by means of screws 242 to the lower end of the shaft 236. The feeler finger carries on its end a hardened point such as a diamond 243 for engaging the interior of the work 244. A knob 245 is secured upon the upper end of the shaft 236. A cap 246 is mounted on the shaft and is held against a shoulder on the shaft by means of a nut 247. The cap 246 rides upon a spring 248 whereby the shaft and the feeler finger are resiliently supported. The cap 246 telescopes over the end of the cylindrical portion 235 and a resilient guard such as rawhide 249 is secured to the cap and secured to the upper end of the cylindrical portion by means of spring bands 250. The resilient guard acts as a protection against dirt and water entering into the bearings which support the shaft 236. A similar guard 251 is secured on the lower end of the cylindrical portion and secured to the shaft 236. An arm 252 is secured by means of screws 253 to the cap 246 and this arm extends beneath the nozzle 232. Oblong slots 254 permit the adjustment of the feeler finger 241 on the shaft 236.

In operation the feeler finger is positioned in the work as indicated in Figures 33 and 34. As the work is reduced in size spring 248 raises the shaft 236 and decreases the area between the bent end of the arm 252 and the outlet of the nozzle 232 to restrict the flow of air from air line 233. A decrease in the flow of air causes mercury to rise and first close circuit between contacts 368 and 370 to operate mechanism which will later be described. A further rise of the mercury closes circuit between contacts 369 and 379 to control other mechanism as the work is reduced to finished size.

Both of the sizing devices make use of a mercury tube and contacts similar to those shown in the application of Harold E. Balsiger Ser. No. 598,498, filed March 12, 1932.

In operation the sizing device is swung into operative position with the diamond on the feeler finger in engagement with the work. The wheel carriage is then moved forward into

grinding position by means of the lever 121. As the wheel carriage moves into grinding position the cam 149 closes limit switch 147. This energizes solenoid 150 and closes switch 260 which connects all of the electrically operated devices to power lines 261, 262, and 263. When switch 260 is closed circuit is closed to the work rotating motor 52 to start this motor. Circuit is also closed through lines 261, 262 and normally closed switch 363 to energize solenoid 146 to open the valve 144 which controls the supply of coolant to the grinding wheel. As the wheel carriage moved into grinding position to stop screw engages pin 264 which engages the end of a lever 265 which operates through a link 266 and lever 267 to shift the valve 164 to the left (Fig. 20). This valve also is connected by an arm 268 to a shaft 269 and link 270 and operating through rock arm 271 and link 272 resets solenoid 273. Spring 274 permits valve to be shifted by the solenoid without releasing the firing pin 264. When the valve 164 is shifted to the left power lines are connected to the oscillating motor 23 to begin oscillation of the work. Fluid also passes to the motor 103 to feed the wheel into the work. The rapid feed of the wheel into the work is checked by the regulator piston 109 and the wheel is then fed through a slow feeding speed. The grinding of the work begins approximately as the speed changes from fast to slow speed and this speed continues until the work is reduced almost to size. When the work has been reduced almost to size the flow of air through the air nozzle is reduced and pressure is built up in the mercury tube to close contacts 369 and 370. This closes circuit through wires 372 and 373 through the electro-magnet 371 to close the switch 374. Closing of switch 374 energizes solenoid 275 to operate a needle valve through arm 276 which limits the flow of fluid out of the chamber 114 to reduce the feeding speed of the work. Closing the switch 374 also energizes electro-magnet 278 to open switch 363 and de-energize solenoid 146 to stop the flow of coolant to the grinding wheel. The finished grinding of the work therefore is at a slow feeding speed and the grinding is done with a dry grinding wheel. This dry grinding of the work polishes the work and at the same time dresses the grinding wheel so that it is unnecessary to re-shape or dress the grinding wheel since it is shaped by the oscillating work during the dry grinding. When mercury is closed across contacts 369 and 370 circuit is closed to energize electro-magnet 280 and close circuit to the solenoid 273 which shifts the valve 164 to direct fluid to back the grinding wheel away from the work and cut-off fluid from the oscillating motor 23. This circuit also energizes solenoid 146 independently of the relay 278 so that the flow of coolant is again started. The operator then moves the lever 121 to the right and backs the grinding wheel away from the work. As the grinding wheel moves back cam 149 allows limit switch 147 to open. This cuts off current to electro-magnet 150 and opens switch 260, de-energizes solenoid 146 again to stop the supply of coolant to the grinding wheel. Cutting off of the current by the main operating switch 150 also deenergizes all of the electrically operated devices on the machine and restores the parts for another operation.

Having thus fully described our said invention, what we claim as new and desire to secure by Letters Patent, is:

1. In a machine of the kind described, a headstock, a headstock spindle, means for oscillating said headstock, means for rotating said spindle comprising a jack shaft extending radially from the center of oscillation, a worm wheel on said shaft means for driving said shaft comprising a shaft having an axis co-incident with the axis of oscillation, a worm gear on said driving shaft adapted to mesh with said worm wheel driving mechanism for said driving shaft, said gearing being adapted to minimize the effect of oscillation on the headstock drive.

2. In a machine of the kind described, a carriage or table, a sizing device responsive to change in size of a work piece, a valve adapted to direct fluid to set various parts of said machine in operation, means responsive to movement of said carriage to shift said valve in one direction, and means responsive to said sizing device to shift said valve in the opposite direction against the action of said carriage responsive means.

3. In a machine of the kind described, a work support, a tool support, means to provide a relative transverse and longitudinal movement of said supports, a supply of coolant, a sizing device responsive to change in size of a work piece, means responsive to said longitudinal movement in one direction to start the flow of said coolant, means responsive to said sizing device to cut off said flow of coolant and thereafter to start it again.

4. In a machine of the kind described a work support, a tool support, means to provide a relative transverse and longitudinal movement between said supports, a coolant supply and means to direct coolant to a work piece, means to oscillate said work support, means to rotate a work piece, means responsive to one of said movements to effect the other and to control said coolant supply, said oscillating means and said work rotating means.

5. A ball race grinder having a work support, means for oscillating the support about an axis which is in vertical alignment with the axis of the surface on the work when finished, a grinding wheel carriage, pressure fluid means for moving said carriage rapidly from the work and rapidly toward the work and pressure fluid means for reducing the speed to slow feed during grinding, and pneumatic means responsive to change in the size of the work in control of the feeding speed of the grinder into the work.

6. In a grinding machine of the kind described, a work support, a wheel support, a wheel mounted therein having a spherical peripheral grinding surface, means for oscillating the work support about an axis coincident with a vertical line thru the center of the peripheral surface of the grinding wheel when in grinding position, means mounted on the oscillating mechanism for rotating the work on its axis, a hydraulic motor for operating the oscillating mechanism, a valve in control of the fluid to said oscillating motor, means for moving the wheel toward and from working position, the valve for operating the oscillating motor being under control of the said wheel carriage.

7. A grinding machine comprising a work carriage, a wheel carriage, pressure fluid means for moving said wheel carriage to feed the grinding wheel into the work, pressure fluid means for oscillating the work support during the grinding, a sizing device, a coolant supply for the grinding wheel, and means operated independ-

ently by movement of the wheel carriage toward and from working position and by the work sizing device for effecting a control of the coolant to the grinding wheel.

8. In a machine of the kind described, a bed, a headstock mounted thereon, a headstock spindle, means for oscillating said headstock comprising a tubular oscillating spindle mounted solely in the bed, a shaft extending thru said spindle, a jack shaft at right angles to said spindle, speed reducing driving connections between said jack shaft and said first mentioned shaft and connections from said jack shaft to said headstock spindle.

9. In a machine of the kind described, a headstock, a headstock spindle, means for oscillating said headstock comprising a tubular spindle mounted solely in the bed, means to oscillate said tubular spindle, a shaft rotatably mounted within said spindle, means to rotate said shaft, a jack shaft rotatably mounted in said headstock at right angles to said oscillating spindle, a worm on said shaft, a worm gear on said jack shaft adapted to engage said worm and connections from said jack shaft to said headstock spindle.

10. In a machine of the kind described a bed, a headstock, a headstock spindle, a tubular oscillating spindle, means to drive said headstock spindle, including a vertical shaft extending thru said oscillating spindle, a section of horizontal webbing forming a compartment in said bed, said shaft and said oscillating spindle being adapted to extend thru said webbing, a pulley on the lower end of said oscillating spindle under said webbing and adapted to drive said shaft, a disk on said oscillating spindle on the opposite side of the webbing from the pulley, said disk and said webbing serving to prevent water or oil from dropping on said pulley.

11. In a machine of the kind described a sizing device consisting of separately mounted portions, one of said portions being mounted in a fixed position relative to a work piece and carrying an element sensitive to change in size of a work piece, the other portion being movable relative to said fixed portion and said work piece and carrying an element adapted to be held resiliently in engagement with the work, means to move said movable portion into and out of operative position, said work engaging element being adapted to cooperate with said sensitive element.

12. In a machine of the kind described, a tool support, a work support mounted on a column for oscillation in said bed, a motor for oscillating said column, said motor being mounted on said column and connections from said motor to said bed comprising relatively slender torque rods whereby the torque reaction only is transmitted from said motor to said bed thereby eliminating any tilting or cramping of the oscillating column.

13. In a machine of the kind described a work support, a tool support, mechanisms to effect relative transverse and longitudinal movements of said supports, a positive stop for said longitudinal movement, means to initiate said transverse movement comprising a valve, an element movably mounted in said stop, connections between said element and said valve and means whereby said element is shifted by said longitudinal movement before said movement is arrested by said stop.

14. In a machine of the kind described, a bed, a wheel support slidably mounted thereon, a

feed mechanism for said wheel support comprising a feed screw, a nut for said feed screw, connections between said nut and said wheel base comprising a clamp bracket, means to shift said feed screw bodily comprising a piston and cylinder attached to the bed, said mechanism being removable from the machine by loosening said clamp and separating the piston and cylinder from the bed.

15. In a machine of the kind described a work support, a tool support, mechanisms to effect relative oscillating and longitudinal movements of said supports, a positive stop for said longitudinal movement, means to initiate said oscillating movement comprising a valve, an element movably mounted in said stop, connections between said valve and said element, said element being adapted to protrude from said stop whereby said element is shifted by said longitudinal movement before said movement is arrested by said stop.

16. In a machine of the kind described, a work support, a tool support, mechanisms to effect relative positioning, feeding and traversing movements between said supports and to rotate a work piece, a coolant supply, a sizing device responsive to changes in size of a work piece, mechanisms responsive to said longitudinal movement in one direction to initiate said feeding and said traversing movements, to start a flow of coolant and to start said work rotating mechanism, mechanisms actuated by said sizing device when the work reaches a predetermined size to slow down the feeding movement and stop the flow of coolant and at a further predetermined size to reverse the feeding movement, stop the traverse movement, and start the flow of coolant again, the mechanisms actuated by said longitudinal movement being effected by said movement, in the opposite direction to again stop the flow of coolant and to stop said work rotating mechanism.

17. In a machine of the kind described, a headstock adapted to be adjusted axially, mechanism to oscillate said headstock, a tool adapted to be moved into operative position relative to said headstock, a sizing device having a finger adapted to engage a work piece, said finger having a fixed operative position relative to the axis about which said headstock oscillates whereby said sizing device remains stationary while said headstock is adjusted axially.

18. In a machine of the kind described, a bed, a work support and a wheel support movably mounted therein, a grinding wheel rotatably mounted in said wheel support, a bracket rigidly secured to said bed, the jack shaft mounted in said bracket at approximately the same level as the grinding wheel, a wheel driving pulley on said jack shaft, a motor, driving connections from said motor to said pulley and additional driving connections from said pulley to said grinding wheel.

19. In a machine of the kind described, a sizing device consisting of separately mounted portions, one of said portions being mounted in a bar in a fixed position relative to a work piece, a slot in said bar, one portion of the bar formed by said slot carrying an element sensitive to change in size of a work piece, the other of said sizing device portions being movable relative to said fixed portion and carrying an element adapted to be held resiliently in engagement

with a work piece, an arm on said movable portion adapted to be moved toward or away from said sensitive element, an adjusting screw threaded in one portion of said bar and bearing on the other whereby to adjust said sensitive element relative to said movable portion.

20. A grinding machine having a bed, a wheel carriage movably mounted thereon, a wheel base mounted to move transversely of said carriage movement, a grinding wheel rotatably mounted on said wheel base, a work support on said bed, mechanism to move said wheel carriage axially of said grinding wheel to place said wheel and a work piece in operative relation, fluid pressure mechanism for moving said wheel base to move the grinding wheel into and out of contact with a work piece, a valve for controlling said fluid pressure, yielding means actuated by said carriage as it moves into operative position to shift said valve to initiate the transverse movement of the wheel base and means actuated when the work reaches a predetermined size to shift said valve to reverse said transverse movement while said carriage remains in operative position.

21. A grinding machine having a bed, a wheel carriage movably mounted thereon, a wheel base mounted to move transversely of said carriage movement, a grinding wheel rotatably mounted on said wheel base, a work support on said bed, mechanism to move said wheel carriage axially of said grinding wheel to place said wheel and a work piece in operative relation, fluid pressure mechanism for moving said wheel base to move the grinding wheel into and out of contact with a work piece, a valve for controlling said fluid pressure, yielding means actuated by said carriage as it moves into operative position to shift said valve to initiate the transverse movement of the wheel base and means actuated when the work reaches a predetermined size to shift said valve to reverse said transverse movement while said carriage remains in operative position, fluid pressure means for oscillating said work support and means whereby said valve which operates to initiate the transverse movement of the spindle also operates to initiate the oscillations of the work support, and means whereby the oscillations of the work support are stopped upon the initiating of the transverse movement of the grinding wheel away from the work.

22. A grinding machine having a bed, a wheel carriage movably mounted thereon, a wheel base mounted to move transversely of said carriage movement, a grinding wheel rotatably mounted on said wheel base, a work support on said bed, mechanism to move said wheel carriage axially of said grinding wheel to place said wheel and a work piece in operative relation, fluid pressure

mechanism for moving said wheel base to move the grinding wheel into and out of contact with a work piece, a valve for controlling said fluid pressure, means actuated by said carriage as it moves into operative position to shift said valve to initiate the transverse movement of the wheel base and means actuated when the work reaches a predetermined size to shift said valve and reverse said transverse movement while said carriage remains in operative position, means for supplying a coolant to the surface of the work being ground including a control valve therefor, means operated by the advancing movement of the carriage for opening the valve to supply coolant to the work and means operating when the work reaches a predetermined size for stopping the flow of the coolant.

23. A grinding machine having a bed, a wheel carriage movably mounted thereon, a wheel base mounted to move transversely of said carriage movement, a grinding wheel rotatably mounted on said wheel base, a work support on said bed, mechanism to move said wheel carriage axially of said grinding wheel to place said wheel and a work piece in operative relation, fluid pressure mechanism for moving said wheel base to move the grinding wheel into and out of contact with a work piece, a valve for controlling said fluid pressure, means actuated by said carriage as it moves into operative position to shift said valve to initiate the transverse movement of the wheel base and means actuated when the work reaches a predetermined size to shift said valve and reverse said transverse movement while said carriage remains in operative position, means for supplying a coolant to the surface of the work being ground including a control valve, means operated by movement of said carriage toward and from the work for opening and closing said coolant control valve, and means operating when the work reaches a predetermined size for stopping the flow of coolant, said means being effective to start the flow of coolant again when the work has been ground to a further predetermined size.

24. In a machine of the kind described a tool support, a work support, mechanisms which effect relative positioning and feeding movements between said supports, a coolant supply, a sizing device responsive to changes in size of a work piece, mechanisms to initiate said feeding movement and to start a flow of coolant, mechanisms controlled by said sizing device operative to stop the flow of coolant when the work reaches a predetermined size and to start the flow of coolant again at a different predetermined size.

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