March 26, 1957 O. E. HILL ET AL 2,786,311

CAM GRINDING MACHINE

Filed May 9, 1955 8 Sheets-Sheet 1

Fig. 1

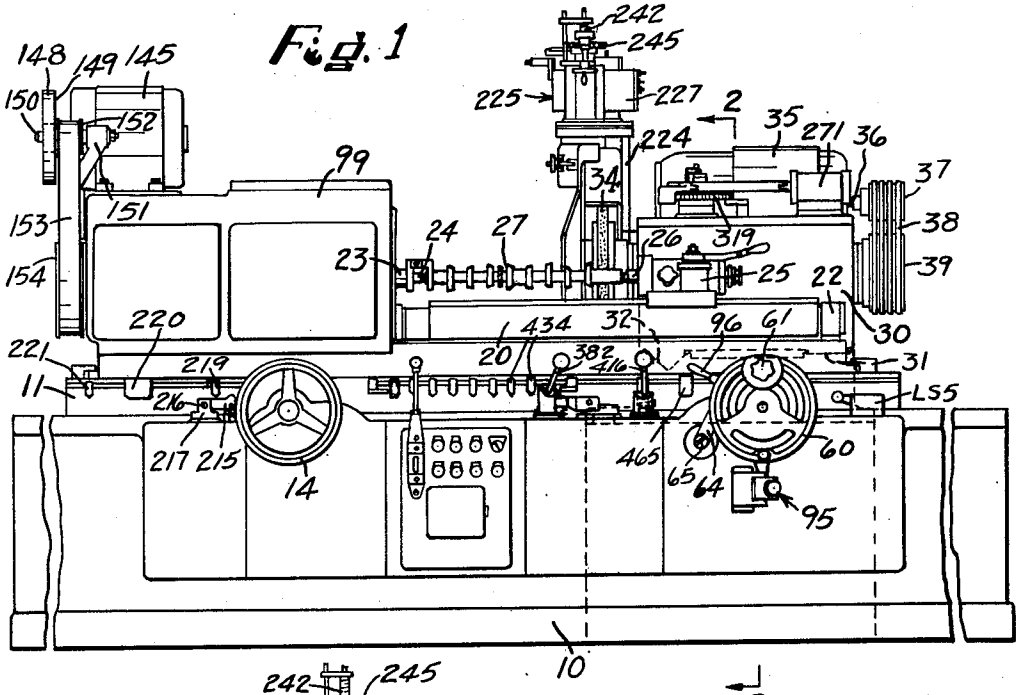
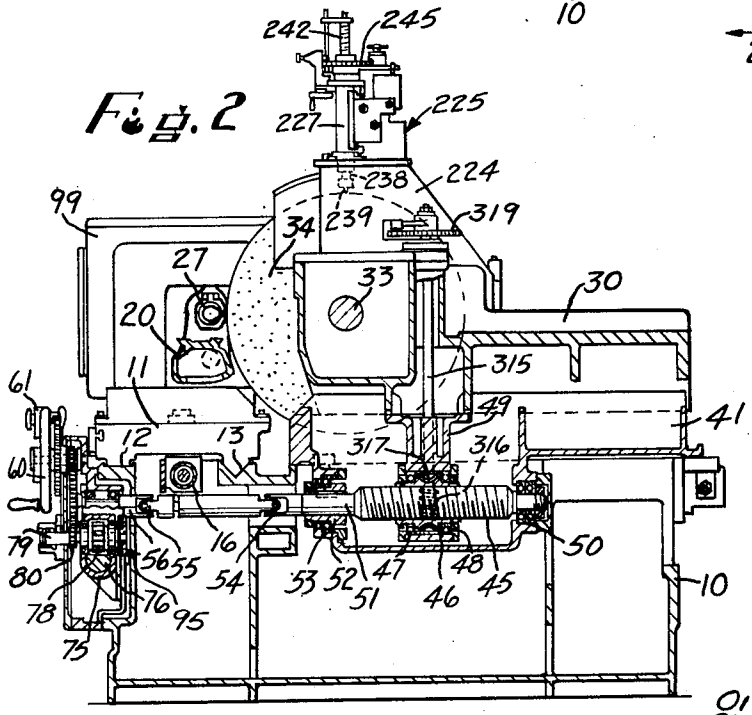


Fig. 2



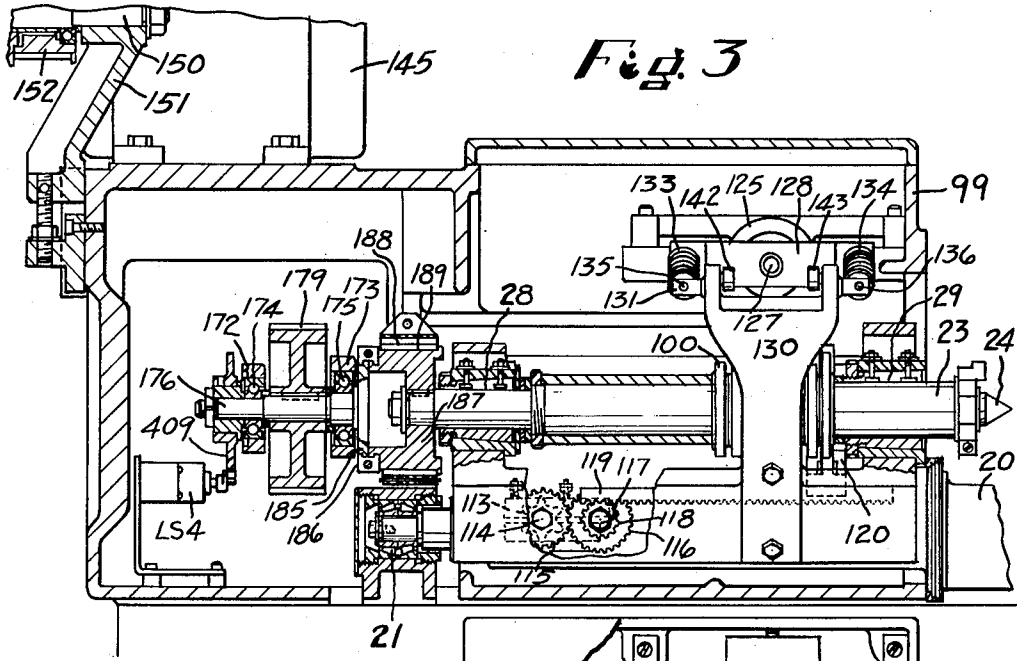
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CAM GRINDING MACHINE

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Fig. 3



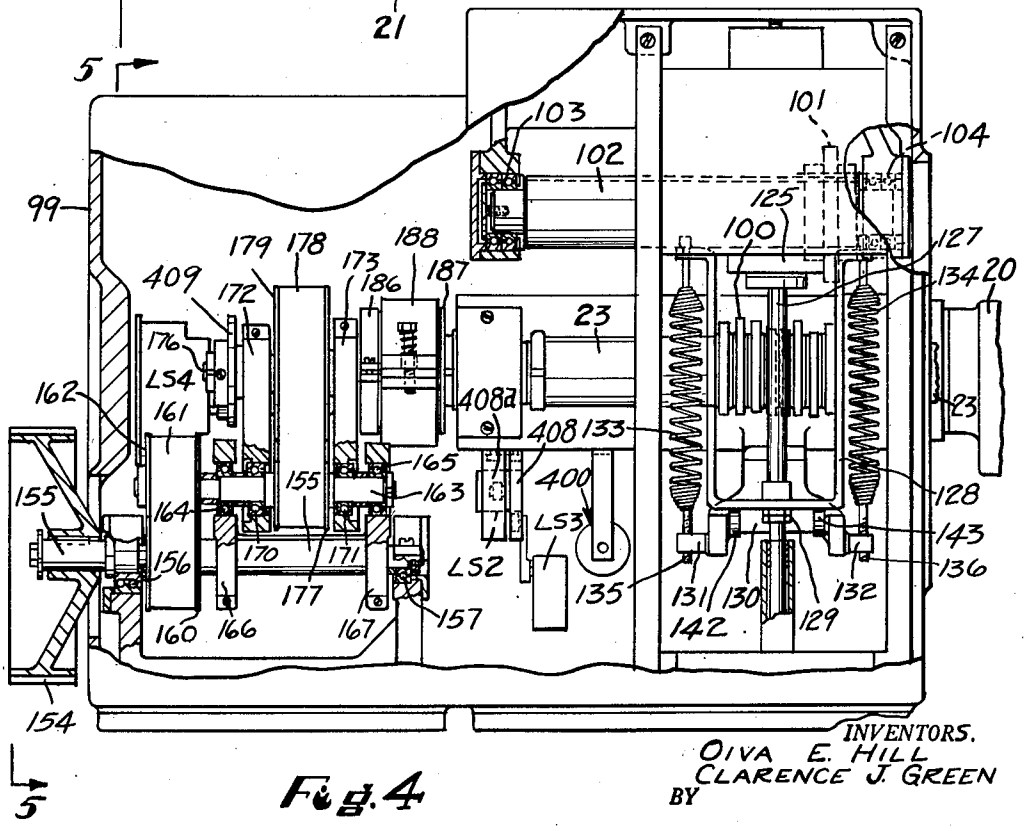


Fig. 4

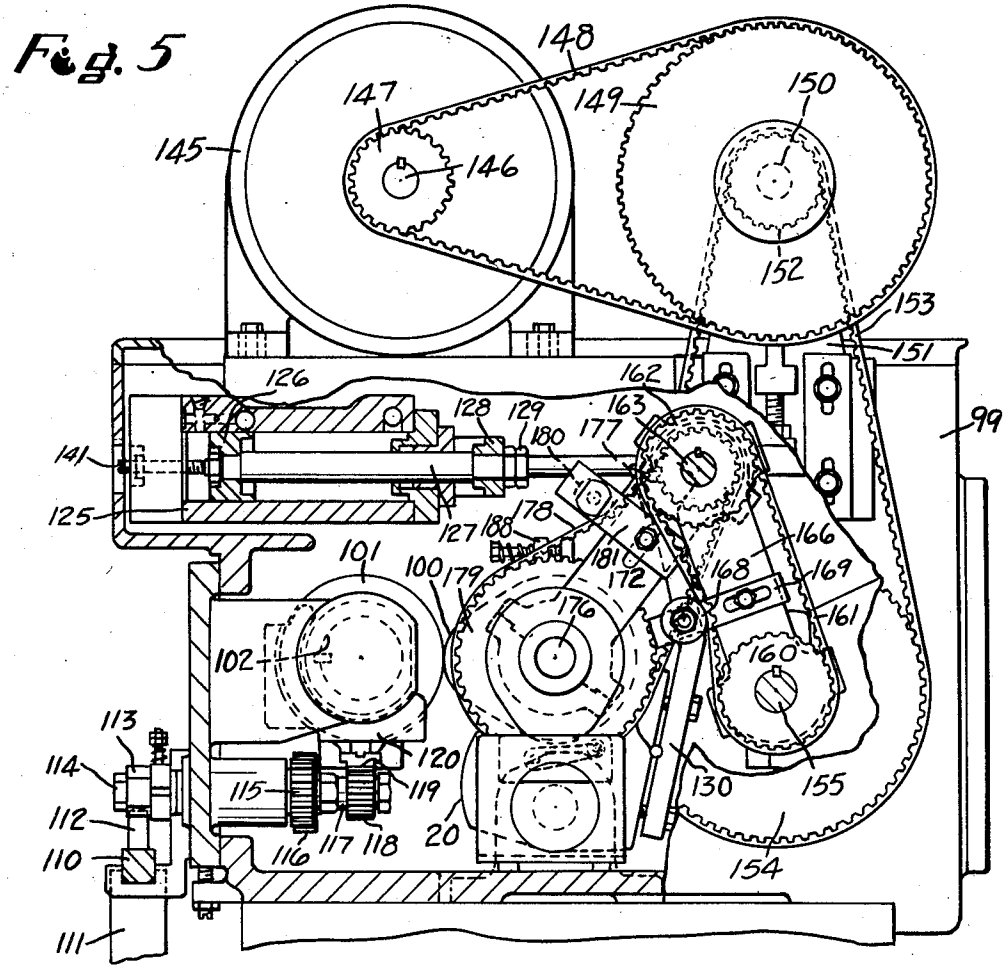
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CAM GRINDING MACHINE

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Fig. 5



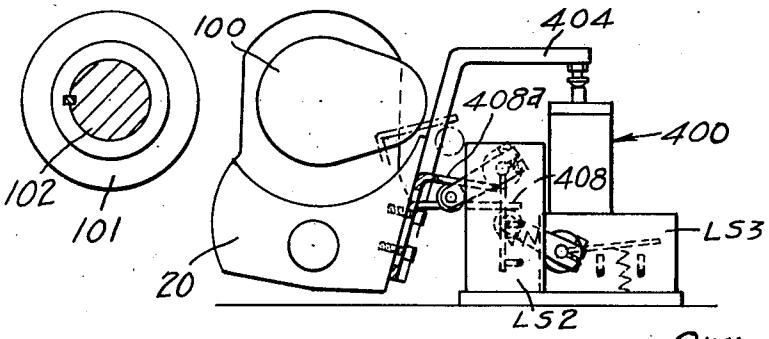


Fig. 18

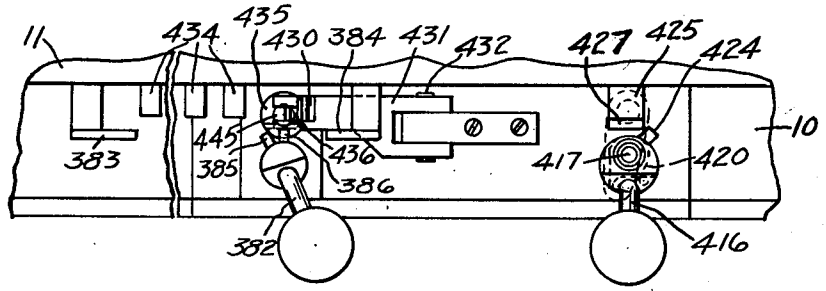
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CAM GRINDING MACHINE

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Fig. 7



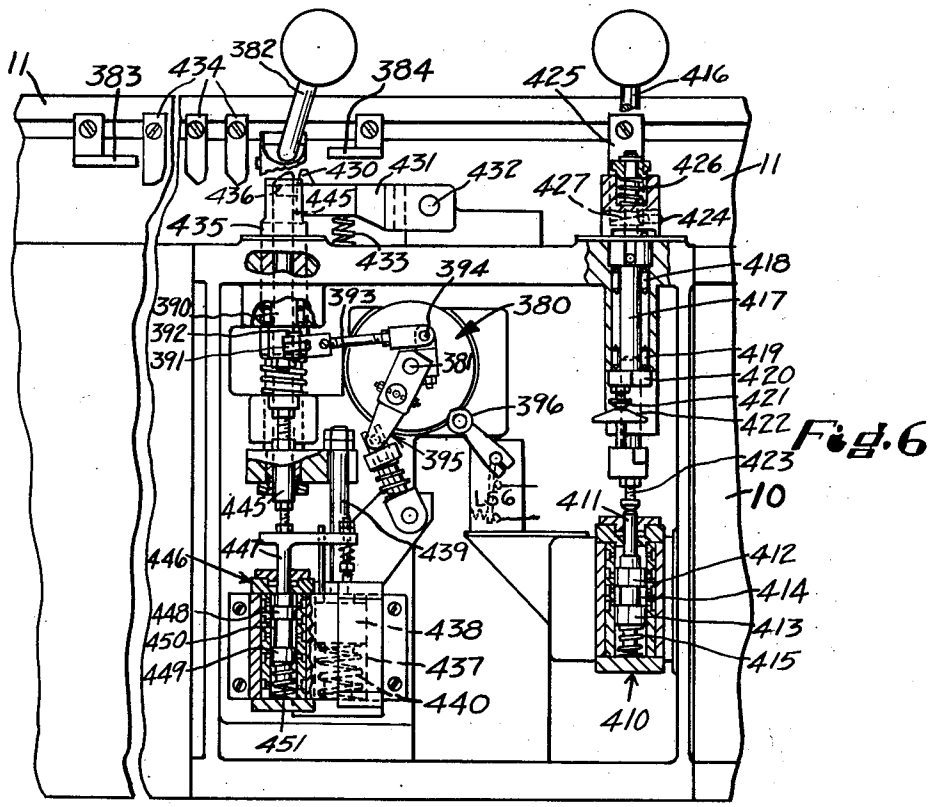


Fig. 6

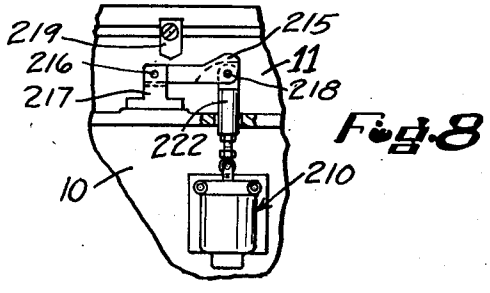


Fig. 8

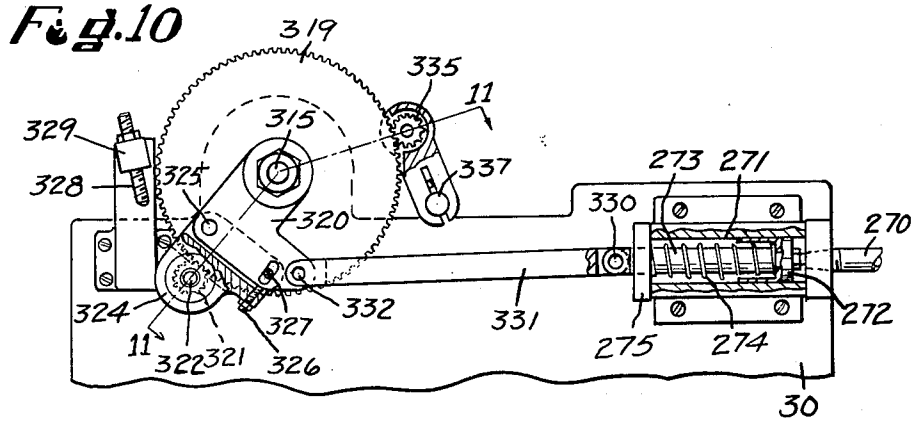
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Fig. 10



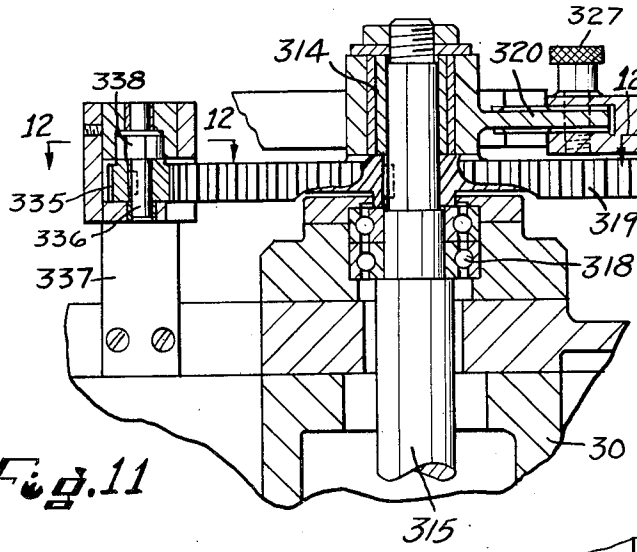


Fig. 11

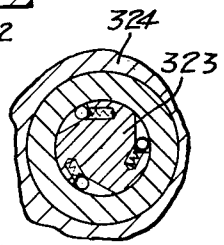


Fig. 12

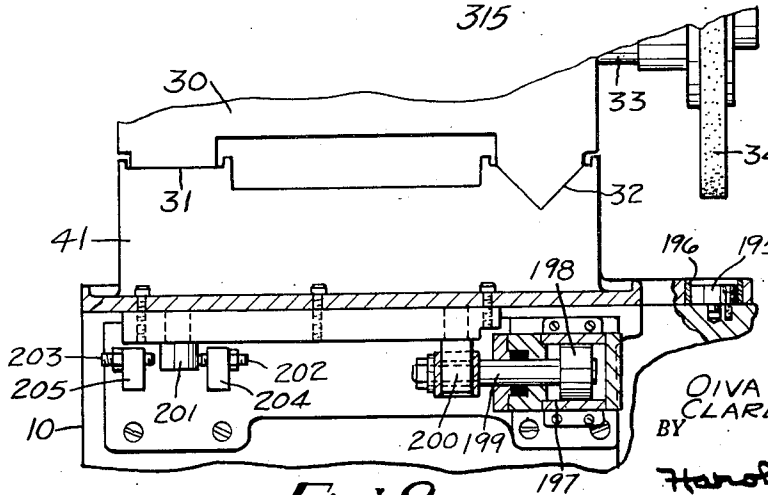


Fig. 9

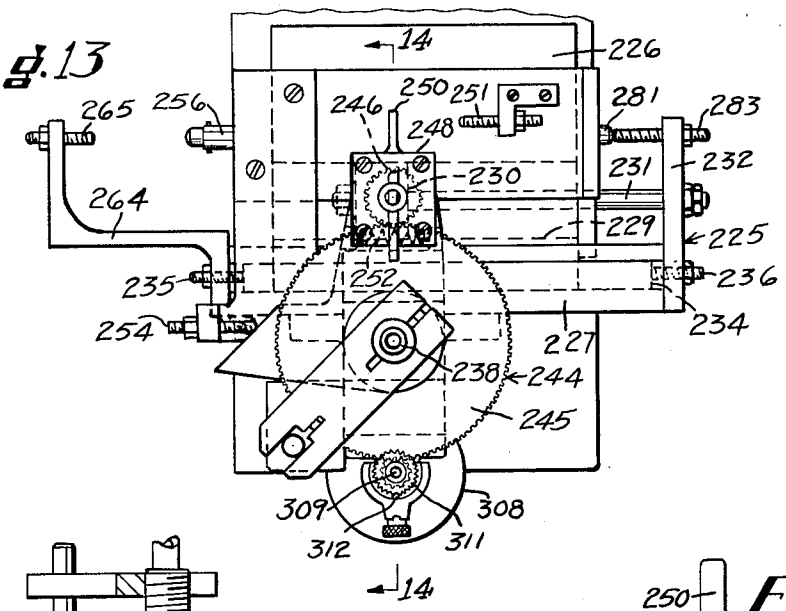
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CAM GRINDING MACHINE

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Fig. 13



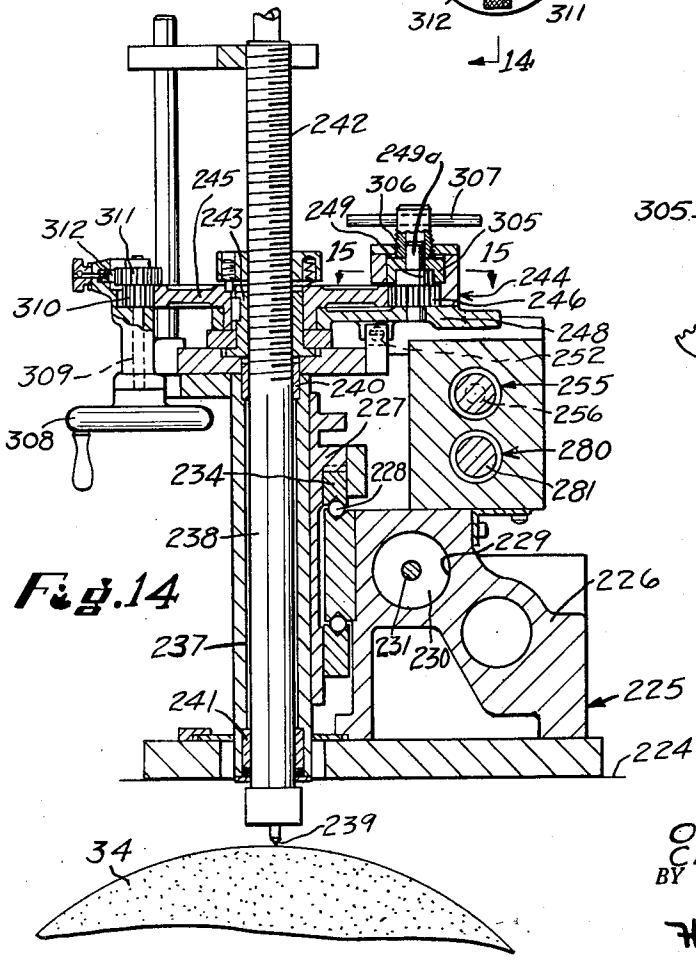


Fig. 14

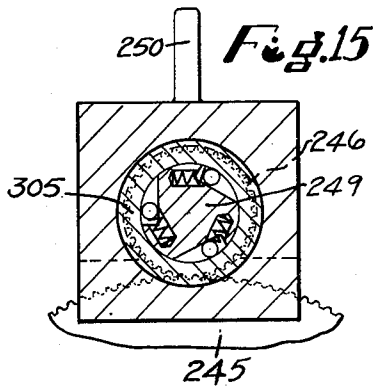


Fig. 15

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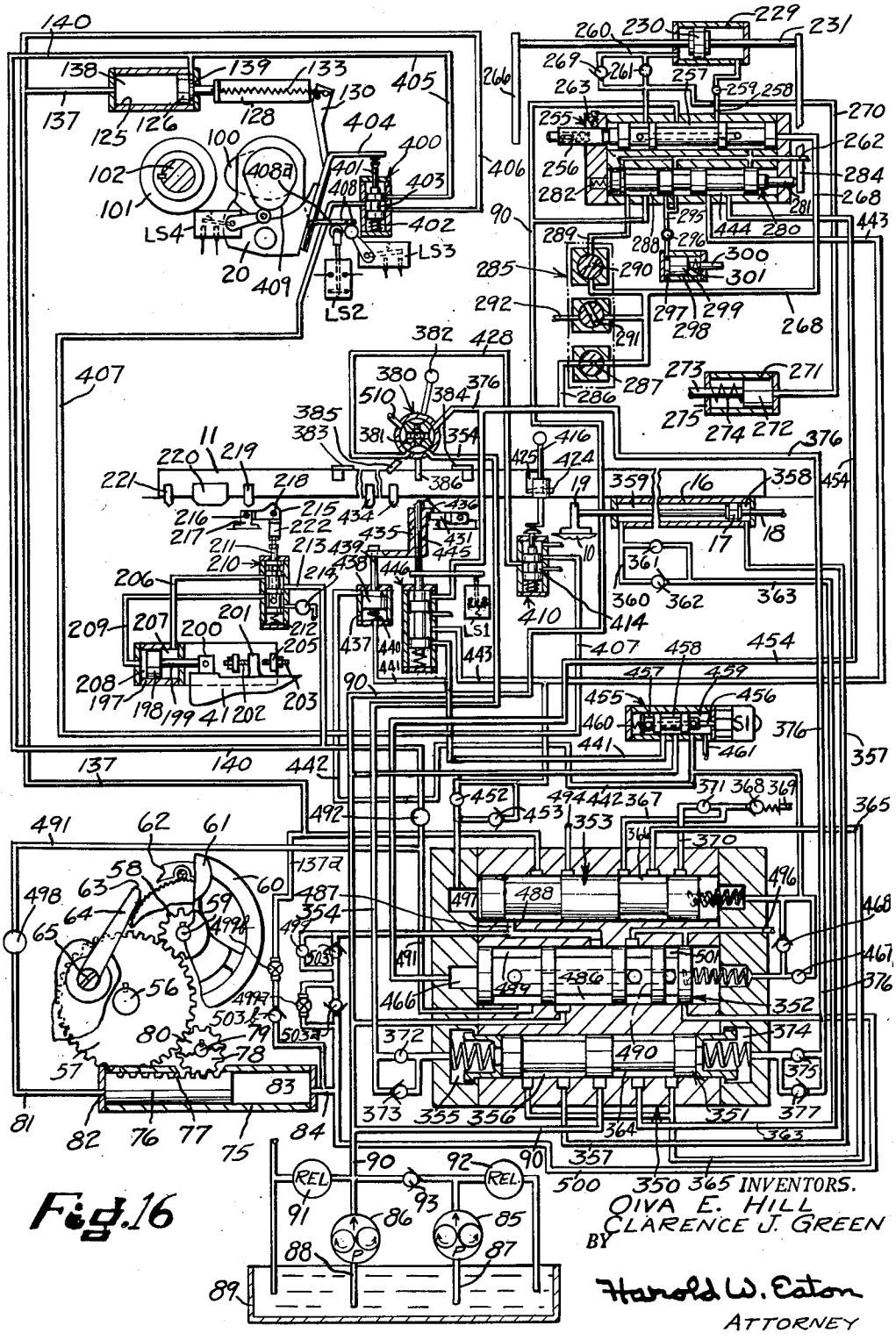


Fig. 16

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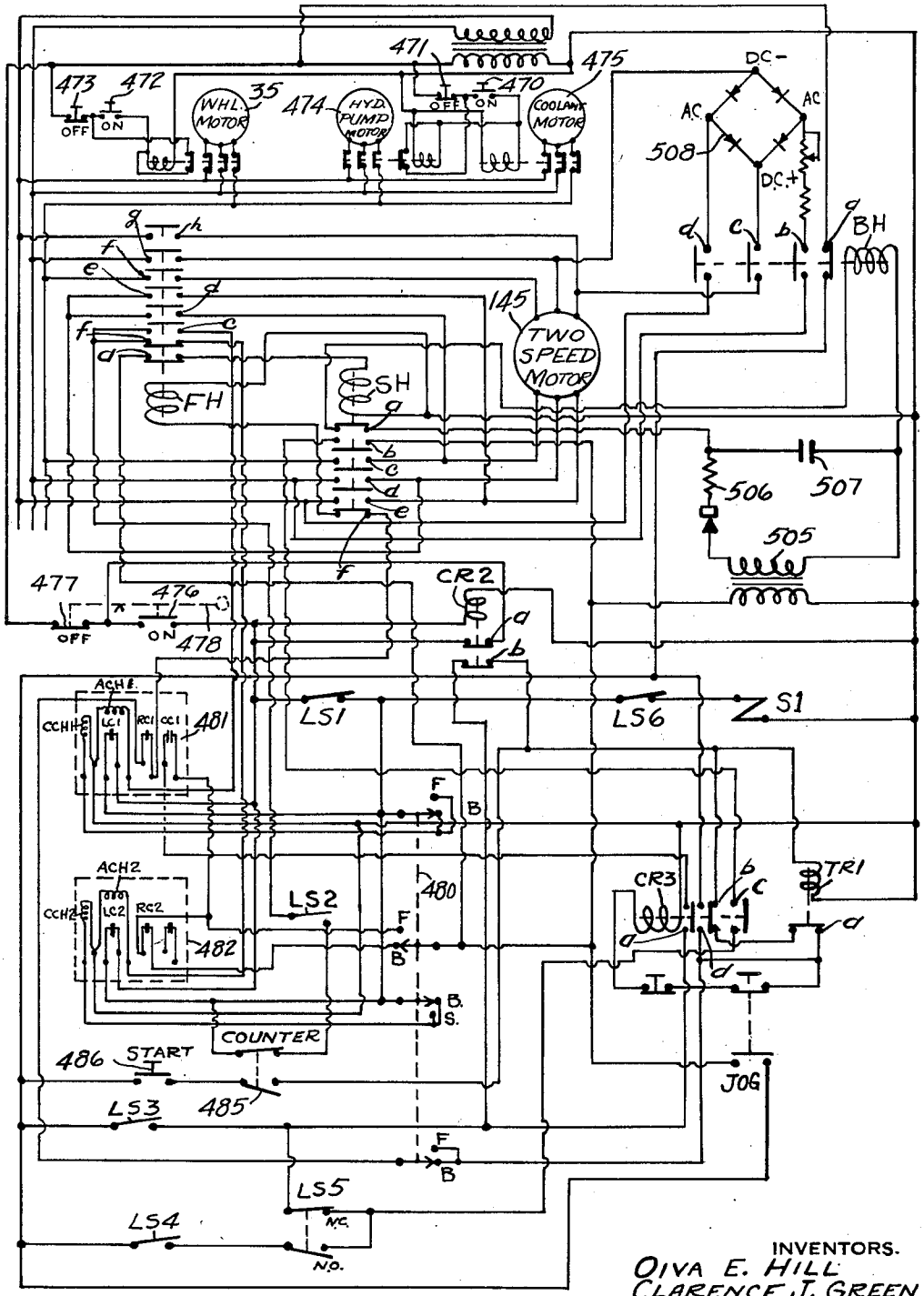


Fig. 17

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United States Patent Office 2,786,311 Patented Mar. 26, 1957

2,786,311

CAM GRINDING MACHINE

Oiva E. Hill and Clarence J. Green, Worcester, Mass., assignors to Norton Company, Worcester, Mass., a corporation of Massachusetts

Application May 9, 1955, Serial No. 506,824

24 Claims. (Cl. 51—101)

The invention relates to grinding machines, and more particularly to an automatically operated cam shaft grinding machine.

One object of the invention is to provide a simple and thoroughly practical automatic grinding machine for grinding a plurality of spaced cams on a cam shaft. Another object is to provide a work drive mechanism for rotating the cam shaft at a fast or initial grinding speed after which the speed is reduced to a slower or final grinding speed. Another object of the invention is to provide a 2-speed work driving mechanism controlled by a pair of electric counters, one of said counters serving to control the duration of the fast or initial grinding speed, and the other counter being arranged to control the duration of the slow or final grinding speed.

Another object of the invention is to provide a selector switch whereby both or either of the counters may be rendered operative so that the machine may be operated only at a fast work speed for initial or rough grinding the cams on a cam shaft, or only at a slow grinding speed for final or finish grinding the cams on a cam shaft, or at both speeds for initial or rough grinding and final or finish grinding each cam during the grinding of each cam on a cam shaft. Another object is to provide a work rotation control mechanism for rotating the work piece at a fast or initial speed, then to slow down to a slow or final speed and to stop rotation of the work after it has been ground to the desired extent and to hold the work piece stationary during indexing movement or positioning the next cam and to start the work piece when the next cam has moved into an operative grinding position.

Another object is to provide a hydraulically operated wheel guard truing apparatus which is arranged automatically to true the periphery of the grinding wheel in timed relation with the grinding cycle. Another object is to provide a selector valve to control the wheel guard truing apparatus to facilitate initiating a truing cycle in timed relation with the shifting of the table reversing valve to true the grinding wheel during the idle stroke of the work table, or to true the operative face of the grinding wheel at any time for a continuous truing operation, or to render the truing apparatus inoperative. A further object of the invention is to provide an interlock between the truing apparatus and the other controls of the machine to prevent movement of the rock bar to an operative position and to prevent initiating an infeed of the grinding wheel before the truing apparatus has completed its cycle of operation. Another object is to provide a suitable interlock to prevent a table indexing movement before the rock bar is rocked to an inoperative position. Other Objects will be in part obvious or in part pointed out hereinafter.

In the accompanying drawings, in which is shown one of various possible embodiments of the mechanical features of this invention:

Fig. 1 is a front elevation of the automatic cam grinding machine;

Fig. 2 is a vertical sectional view, taken approximately on the line 2—2 of Fig. 1, through the grinding machine showing the wheel feeding mechanism;

Fig. 3 is a vertical sectional view, on an enlarged scale, through the work head, showing the master cam assembly and associated parts;

Fig. 4 is a plan view, on an enlarged scale, of the work head with the cover plate broken away and parts shown in section to illustrate the construction;

Fig. 5 is a cross sectional view, on an enlarged scale, taken approximately on the line 5—5 of Fig. 4, through the work head showing the driving mechanism for the master cam shaft and the work spindle;

Fig. 6 is a fragmentary front elevation, on an enlarged scale, of the control apron with the cover plate removed and parts shown in section;

Fig. 7 is a fragmentary plan view of the control apron as shown in Fig. 6;

Fig. 8 is a fragmentary front elevation, on an enlarged scale, of the control valve mechanism for controlling the swivelling movement of the wheel slide;

Fig. 9 is a fragmentary rear elevation, on an enlarged scale, of the wheel slide showing the swivelling mechanism therefor in section;

Fig. 10 is a fragmentary plan view, on an enlarged scale, of the wheel feed compensating mechanism having parts broken away and shown in section to clarify the construction;

Fig. 11 is a vertical sectional view on an enlarged scale, taken approximately on the line 11—11 of Fig. 10 through the wheel feed compensating mechanism;

Fig. 12 is a fragmentary horizontal sectional view, on an enlarged scale, taken approximately on the line 12—12 of Fig. 11, through the overrunning or ball clutch;

Fig. 13 is a fragmentary plan view, on an enlarged scale, of the grinding wheel truing apparatus;

Fig. 14 is a vertical sectional view, taken approximately on the line 14—14 of Fig. 13, through the grinding wheel truing apparatus;

Fig. 15 is a fragmentary horizontal sectional view, on an enlarged scale, taken approximately on the line 15—15 of Fig. 14, through the overrunning or ball clutch;

Fig. 16 is a hydraulic diagram of the actuating mechanisms of the machine;

Fig. 17 is an electrical diagram of the electrical controls of the machine; and

Fig. 18 is a fragmentary diagrammatic view of the rock bar and the actuating limit switch showing an alternative arrangement for separating grinding wheel from the cam being ground.

An automatic cam grinding machine has been illustrated in the drawings having a base 10 which supports a longitudinally movable work table 11 on the usual flat way 12 and V-way 13. The table 11 is arranged so that it may be traversed longitudinally by a manually operable traverse mechanism including a hand wheel 14. This manual traversing mechanism is substantially identical with that shown in the expired patent to C. H. Norton No. 762,838, dated June 14, 1904, to which reference may be had for details of disclosure not contained herein. The table is arranged so that it may be traversed or indexed longitudinally by a power operated mechanism which comprises a hydraulic cylinder 16 (Fig. 16) fixedly mounted on the underside of the work table 11. The cylinder 16 contains a piston 17 which is connected to a double end piston rod 18, the ends of which are fastened to the base 10 by a pair of brackets 19, only one of which has been illustrated in Fig. 16. The hydraulic control mechanism for controlling the admission to and exhaust of fluid from the cylinder 16 will be described hereinafter.

The work table 11 serves as a support for a pivotally

mounted rock bar 20 which is journalled in a pair of spaced bearings 21 (Fig. 3) and 22 (Fig. 1) and an intermediate bearing (not shown) fixedly mounted on the table 11. The rock bar 20 supports a rotatably mounted master cam and work supporting spindle 23 having a head stock center 24. The spindle 23 is rotatably supported by a pair of spaced bearings 28 and 29 (Fig. 3) carried by the rock bar 20. The rock bar 20 also supports a footstock 25 having a footstock center 26. The centers 24 and 26 serve rotatably to support a cam shaft 27 to be ground having a plurality of integrally formed cams thereon.

The base 10 also serves as a support for a transversely movable wheel slide 30 which is arranged to slide transversely on a flatway 31 and a V-way 32 formed on the upper surface of a wheel slide base 41. The wheel silde base 41 is supported on the machine base 10. The wheel slide 30 supports a rotatably mounted wheel spindle 33 having a grinding wheel 34 mounted on the left hand end thereof (Fig. 1). A motor driven mechanism is provided for driving the wheel spindle 33 and the grinding wheel 34 comprising an electric motor 35 mounted on the upper surface of the wheel slide 30. The motor 35 is provided with a motor shaft 36 carrying a multiple V-groove pulley 37 which is connected by multiple V-belts 38 with a multiple V-groove pulley 39 mounted on the right hand end of the wheel spindle 33 (Fig. 1).

Wheel feed

The wheel slide 30 is arranged for a transverse feeding movement relative to the base 10 to feed the grinding wheel 34 toward and from the cam shaft 27 to be ground. This mechanism may comprise a rotatable feed screw 45 supported by the base 10. The feed screw 45 meshes with or engages a rotatable feed nut 46 which is rotatably supported by a pair of spaced anti-friction bearings 47 and 48 (Fig. 2). The bearings 47 and 48 are in turn supported in a bracket 49 depending from the underside of the wheel slide 30. The right hand end of the feed screw 45 (Fig. 2) is rotatably journalled in an anti-friction bearing 50 supported by the base 10. The left hand end of the feed screw 45 is provided with a reduced cylindrical end portion 51 which is slidably keyed in a sleeve 52. The sleeve 52 is rotatably journalled in an anti-friction bearing 53.

The cylindrical end portion 51 of the feed screw 45 is connected by a universal joint 54 and a universal joint 55 with the right hand end of a rotatable shaft 56 which is rotatably journalled in bearings carried by the base 10. A gear 57 is mounted on the left hand end of the shaft 56 (Figs. 2 and 16) which meshes with a small gear 58 which is rotatably supported on a shaft 59. A manually operable feed wheel 60 is also rotatably mounted on the shaft 59 and is fixedly connected to the gear 58. It will be readily apparent from the foregoing disclosure that a rotary motion of the feed wheel 60 will be transmitted through the mechanism above described to impart a rotary motion to the feed screw 45 to impart a corresponding transverse movement to the wheel slide 30 and the grinding wheel 34.

The feed wheel 60 is provided with the old and well known micrometer adjusting mechanism 61 which is arranged to adjust the position of a stop abutment 62 relative to the wheel 60. The stop abutment 62 is arranged in the path of a stop surface 63 formed on the upper end of a feed pawl 64. The feed pawl 64 is pivotally supported by a stud 65 on the front of the machine base 10. It will be readily apparent from the foregoing disclosure that a manual rotation of the feed wheel 60 in a counter-clockwise direction will be transmitted through the mechanism above described to impart a rotary motion to the feed screw 45 thereby causing a forward feeding movement of the wheel slide 30 and the grinding wheel 34. This forward feeding movement continues until the abutment 62 moves into engagement with a stop surface 63.

A power operated feeding mechanism is provided so that the feed screw may be rotated automatically to cause a movement of the wheel slide 30 and grinding wheel 34 toward and from the cam shaft 27 to be ground. This mechanism may comprise a hydraulic cylinder 75 (Figs. 2 and 16) which contains a slidably mounted piston 76. The upper surface of the piston 76 is provided with rack teeth 77 which mesh with a small gear 78 which is keyed onto a rotatable shaft 79. The shaft 79 carries a gear 80 which meshes with gear 57 so that movement of the piston 76 will be imparted through the rack 77, the gear 78, the gear 57 to impart a rotary motion to the feed screw 45. When it is desired to initiate a forward feeding movement of the grinding wheel to grind a cam on the cam shaft 27, fluid under pressure is passed through a pipe 81 into a cylinder chamber 82 to move the piston 76 toward the right (Fig. 16) so as to impart a counter-clockwise rotary motion to the feed wheel 60 and to impart a rotary motion to the feed screw 45 to cause a forward movement of the grinding wheel slide 30 and the grinding wheel 34. During this movement fluid within a cylinder chamber 83 may exhaust through a pipe 84.

Similarly when it is desired to cause a rearward movement of the grinding wheel, fluid under pressure is passed through the pipe 84 into the cylinder chamber 83 to cause a movement of the piston 76 toward the left which movement is transmitted through the gears above described to impart a clockwise rotation to the feed wheel 60 and to impart a rotary motion to the feed screw 45 so as to cause a rearward movement of the slide 30 to an inoperative position.

Fluid pressure system

A fluid pressure system is provided for supplying fluid under pressure for the several actuating mechanisms of the machine to be hereinafter described. This mechanism may comprise a motor driven Hi-Low pump comprising a low pressure high volume pump 85 and a high pressure low volume pump 86 which are arranged to draw fluid through a pipe 87 and a pipe 88 respectively from a reservoir 89 and to force fluid under pressure through a pipe 90. A relief valve 91 is provided in the pipe line 90 for returning excess fluid under pressure directly to the reservoir 89 from the pump 86. Similarly a relief valve 92 is provided for allowing excess fluid under pressure from the pump 85 to pass directly to the reservoir 89. A ball check valve 93 is provided between the pump 85 and the pressure pipe 90. In the normal operation of the machine, the pump 86 supplies fluid under high pressure and low volume to the various operating mechanisms of the machine. If there is insufficient volume of fluid in the system for actuating the various mechanisms, the ball check valve 93 opens and the pressure supply in the pipe 90 is supplemented by fluid under low pressure of high volume from the pump 85.

To facilitate setting up the feeding mechanism of the machine when a new grinding wheel is mounted thereon, to set up for different diameters of work pieces, or to facilitate a manual control of the wheel feed during a grinding operation, it is desirable to provide means for disconnecting the feed wheel 60 from the power actuated mechanism. This is preferably accomplished by means of a clutch mechanism 95 which is actuated by a manually operable lever 96 (Fig. 1). This clutch mechanism has not been illustrated in detail since it is identical with that shown in our prior U. S. Patent No. 2,535,130 dated December 26, 1950, to which reference may be had for details of disclosure not contained herein.

Rock bar actuation

The left hand end of the rock bar 20 supports the headstock spindle 23 in a manner hereinbefore described which

is contained within a headstock housing 99. The headstock spindle 23 serves as a master cam spindle for supporting a plurality of master cams 100, one master cam for each cam on the cam shaft 27 to be ground. A rotatable slidably mounted master cam follower roller 101 is slidably keyed on a rotatable shaft 102 (Fig. 4). The shaft 102 is journalled in spaced bearings 103 and 104 which are fixedly mounted in the head stock housing 99. During a grinding operation the master cam 100 is maintained in operative engagement with the follower roller 101 by a yieldable means to be hereinafter described so that as the headstock spindle 23 and the master cams 100 are rotated, the master cam 100 will rotate against the follower roller 101 to impart a controlled working movement to the rock bar 20 so as to generate a predetermined contour on the cam being ground.

Index-master cam follower

An indexing mechanism is provided for automatically indexing the master cam roller 101 longitudinally on the shaft 102 in timed relation with the longitudinal indexing movement of the table 11 automatically to position the follower roller 101 opposite the master cam 100 corresponding to the cam in the camshaft 27 to be ground. This indexing mechanism may comprise a dog bar 110 (Fig. 5) which is fixedly supported by a bracket 111 on the base 10. The dog bar 110 is provided with a plurality of adjustably mounted dogs 112, only one of which has been illustrated in Fig. 5, which are arranged in the path of a star wheel 113 (Figs. 3 and 5). The star wheel is mounted on the end of a rotatable shaft 114, the inner end of which supports a gear 115. The gear 115 meshes with a gear 116 which is mounted on a rotatable shaft 117. The shaft 117 carries a gear 118 which meshes with a rack bar 119 which is slidable longitudinally relative to the headstock housing 99. A yoked member 120 engages the side face of the master cam roller 101 and is fixedly mounted to the rack bar 119. This mechanism for indexing the master cam roller 101 is substantially identical with the mechanisms shown in the expired U. S. Patent No. 1,783,755 to Trefethen and Belden dated December 2, 1930, and also expired U. S. Patent No. 2,022,178 to Belden and Silven dated November 26, 1935, to which reference may be had for details of disclosure not contained herein. It will be readily apparent from the foregoing disclosure that when the table 11 is indexed longitudinally to position successive cams on the cam shaft 27 to be ground, an indexing movement will be imparted to index the master cam roller 101 longitudinally automatically to position the roller 101 in operative relation with the corresponding master cam 100.

A fluid pressure mechanism is provided for rocking the rock bar 20 to and from an operative position. This mechanism may comprise a cylinder 125 which contains a slidably mounted piston 126 connected to one end of a piston rod 127. The other end of the piston rod 127 is connected to a U-shaped frame 128 which is clamped thereon by means of nuts 129 (Fig. 4). An upwardly extending arm 130 is fixedly mounted on the rock bar 20. The upper end of the arm 130 is provided with a pair of horizontally extending arms 131 and 132. A pair of tension springs 133 and 134 are connected at one end to the opposite ends of the U-shaped frame 128. The other ends of the springs 133 and 134 are connected by adjusting screws 135 and 136 respectively to the arms 131 and 132 (Fig. 4). By adjusting the screws 135 and 136, the tension of the springs 133 and 134 may be varied as desired so as to maintain the desired operating pressure between the master cam 100 and the follower roller 101. The arms 131 and 132 on the arm 130 are provided with rollers 142 and 143 respectively which are arranged to be engaged by the U-shaped frame 128 when the piston 126 is moved toward the right (Fig. 16). When fluid under pressure is passed through a pipe 137 into a cylinder chamber 138 to move the piston 126 toward the right, the U-shaped frame 128 will be moved into engagement with the rollers 142 and 143 after which continued movement of the piston 126 toward the right swings the arm 130 in a clockwise direction (Fig. 16) to impart a clockwise movement to the rock bar 20 thereby separating the master cam 100 from the follower roller 101. During this movement of the piston 126, fluid within a cylinder chamber 139 may exhaust through a pipe 140. The adjusting screws 135 and 136 are preferably adjusted so that when the piston 126 is in its extreme left hand end position (Fig. 16), the tension of the springs 133 and 134 will be sufficient to maintain the master cam 100 in operative engagement with the periphery of the follower roller 101 during rotation of the headstock spindle 23 so that the master cam 100 will impart a controlled rocking movement to the rock bar 20 during a cam grinding operation.

As the piston 126 moves toward the right to shift the rock bar 20 to an inoperative position, the U-shaped frame 128 moves toward the right and due to the clearance between the U-shaped frame 128 and the rollers 142 and 143 relieves the tension on the springs 133 and 134 respectively. During movement of the piston 126 and the U-shaped frame 128 toward the right, the frame 128 engages the rollers 142 and 143 respectively and rocks the arm 130 in a clockwise direction (Fig. 16) to rock the rock bar 20 to an inoperative position as illustrated in Fig. 16. By utilizing this construction, the extending and contracting of the springs 133 and 134 is reduced to a minimum. During movement of the piston 126 toward the left, the master cam 100 moves into engagement with the follower roller 101 after which the continued movement of the U-shaped frame 128 toward the left (Fig. 16) separates the frame 128 from the rollers 142 and 143 and increases the tension on the springs 133 and 134 to the desired operating tension. The movement of the piston 126 toward the left continues until the piston 126 engages an adjustable stop screw 141 (Fig. 5) carried by the cylinder head at the left hand end of the cylinder 125.

Work drive

A work driving mechanism is provided for imparting a rotary motion to the headstock spindle 23 and the master cams 100. This driving mechanism is preferably a belt drive in which Gilmer timing belts are utilized which ride upon pulleys cut with grooves which resemble a sprocket. An electric motor 145 is mounted on the upper surface of the headstock housing 99 which is supported on the table 11. The motor 145 is provided with a motor shaft 146 having a pulley 147 keyed thereon. The pulley 147 is connected by a belt 148 with a pulley 149 mounted on a rotatable shaft 150. The shaft 150 is rotatably supported on a bracket 151 which is fixedly mounted on the left hand end of the headstock housing 99 (Figs. 1 and 3). The shaft 150 is provided with a pulley 152 which is connected by a belt 153 with a pulley 154 mounted on a rotatable shaft 155 which is journalled in spaced bearings 156 and 157 (Fig. 4) fixedly mounted relative to the headstock housing 99.

An intermediate shaft is provided which is connected by spacer arms with the shaft 155 and also with a driven shaft 176 which is axially aligned with the headstock spindle 23. The shaft 155 is provided with a pulley 160 which is connected by a belt 161 with a pulley 162 keyed onto a rotatable shaft 163. A pair of spaced bearings 164 and 165 carried by a pair of arms 166 and 167 serve as a support for the shaft 163. An idler roller 168 rotatably supported on an adjustable bracket 169 serves to tension the driving belt 161. The bracket 169 is adjustably supported on the side face of the arm 166.

The shaft 163 is provided with a pair of spaced bearings 170 and 171 which support the upper ends of a pair of spaced arms 172 and 173 respectively. The lower ends of the arms 172 and 173 are connected by bear-

ings 174 and 175 respectively with the rotatable shaft 176 which is arranged in axial alignment with the headstock spindle 23. The bearings 174 and 175 are supported within the headstock housing 99. The shaft 163 is provided with a pulley 177 which is connected by a belt 178 with a pulley 179 keyed on the shaft 176. An idler roller 180 is rotatatbly supported on a bracket 181 which is adjustably supported on the arm 173 and serves to facilitate tensioning the belt 178 as desired.

The shaft 176 is operatively connected to transmit a rotary motion to the axially aligned headstock spindle 23. The shaft 176 is provided with an integral flange 185 which is connected by means of a split ring 186 with a flange sleeve 187 which is keyed onto the left hand end of the headstock spindle 23. A friction band or brake 188 surrounds the outer peripheral surface 189 of the sleeve 187 and serves to provide an adjustable braking action which eliminates backlash in the work driving mechanism above described.

In order to grind tapered faces on the cams of a camshaft, the wheel slide base 41 is pivotally supported so that it may be swiveled in a horizontal plane. A pivot stud 195 (Fig. 9) is fixedly supported on the base 10. The wheel slide base 41 is provided with a bearing 196 which mates with or fits on the stud 195.

A hydraulically operated mechanism is provided for imparting a swivelling movement to the wheel slide base 41 and the wheel slide 30. This mechanism may comprise a cylinder 197 which is fixedly mounted on the base 10. The cylinder 197 contains a slidably mounted piston 198 (Figs. 9 and 16). The piston 198 is connected to the end of a piston rod 199, the other end of which is connected to a bracket 200 depending from the underside of the wheel slide base 41.

A stop mechanism is provided for determining the extent of the swivelling movement of the wheel slide base 41 in either direction. This mechanism comprises a stud 201 depending from the underside of the wheel slide base 41. A pair of adjustable stop screws 202 and 203 are suppored by lugs 204 and 205 respectively which are fixedly mounted on the base 10. By adjusting the stop screws 202 and 203, the extent of swivelling movement of the wheel slide base 41 in either direction may be readily adjusted.

Fluid under pressure passing through a pipe 206 into a cylinder chamber 207 in the cylinder 197 serves to impart a swivelling movement of the wheel slide base 41 and the wheel slide 30 in one direction which movement is limited by the stud 201 engaging the stop screw 203. During this swivelling movement, fluid within a cylinder chamber 208 may exhaust through a pipe 209.

A control valve 210 is provided for controlling the admission to an exhaust of fluid from the cylinder 197. The valve 210 is a piston type valve having a valve stem 211 which is normally maintained in an uppermost position by means of a compression spring 212. Fluid under pressure passes through a pipe 213 to the valve 210 and in the position of the valve 210 (Fig. 16) passes through the valve 210, through the pipe 206 into the cylinder chamber 207 to move the piston 198 to swivel the wheel slide base 41 until the stud 201 carried by the wheel slide base 41 engages the stop screw 202.

The valve 210 is preferably actuated by and in timed relation with the longitudinal movement of the work table 11. A lever 215 is pivotally supported by a stud 216 carried by a bracket 217 fixedly mounted relative to the base 10. The lever 215 is connected by a stud 218 with the upper end of a plunger 222. The plunger 222 (Fig. 8) is aligned with the valve stem 211 so that movement of the lever 215 causes a vertical movement of the valve stem 211. The work table 11 is provided with a plurality of adjustable dogs 219, 220 and 221, the lower surfaces of which are arranged to engage an upwardly extending portion of the lever 215 as the table 11 is moved longitudinally to depress the valve stem 211 so that fluid under pressure from the pipe 213 passes through the valve 210, through the pipe 209 into the cylinder chamber 208 to swivel the wheel slide base 41 and the wheel slide 30 in the opposite direction. This swivelling movement continues until the stud 201 engages the stop screw 203 to determine the position of the grinding wheel 34 for grinding a taper in the opposite direction on the cam being ground. Fluid exhausting from the control valve 210 passes through a throttle valve 214 by means of which the rate of swivelling movement of the wheel slide base 41 may be readily controlled.

A grinding wheel truing apparatus is provided whereby the peripheral surface of the grinding wheel may be trued automatically in timed relationship with the cycle of operation, or may be trued continuously when desired. If it is desired to true automatically during the cycle of operation, the truing tool is arranged so that it makes one complete reciprocation across the periphery of the grinding wheel. In case a continuous truing operation is desired, the truing tool is reciprocated continuously until the desired truing operation has been completed. As illustrated in the drawings, a wheel guard 224 surrounds the grinding wheel 34. The wheel guard 224 serves as a support for a truing apparatus 225 (Figs. 1, 2 and 14).

The truing apparatus may comprise a truing apparatus base 226 (Fig. 14) which is fastened to the upper surface of the wheel guard 224. A longitudinally traversable slide 227 is mounted on an anti-friction slideway 228 which is supported by the truing apparatus base 226. The slideway 228 is arranged to facilitate a longitudinal traversing movement of the slide 227 in a direction parallel to the axis of the grinding wheel 34.

A hydraulically operated mechanism is provided for traversing the slide 227 longitudinally comprising a cylinder 229 which is formed within the truing apparatus base 226. The cylinder 229 is provided with a slidably mounted piston 230 connected to one end of a piston rod 231. The other end of the piston rod 231 is connected to a bracket 232 which is fastened to the right hand end of the slide 227 (Fig. 13). In order to facilitate taking up lost motion in the anti-friction slideway 228, an upper longitudinally extending member 234 of the slideway 228 is supported by the slide 227 and is tapered so that a longitudinal adjustment thereof serves to eliminate lost motion between the anti-friction slideway parts. As shown in Fig. 13 a pair of adjusting screws 235 and 236 are provided to facilitate a longitudinal adjustment of the tapered member 234. It will be readily apparent from the foregoing disclosure that by manipulation of the screws 235 and 236, lost motion between the anti-friction slide parts may be adjusted as desired.

The longitudinally movable slide 227 is provided with a transversely extending vertically arranged aperture 237 which serves as a support for a truing tool carrier 238 having a diamond or truing tool 239 mounted at the lower end thereof. The truing tool carrier 238 is supported in spaced bearings 240 and 241 which are carried by the slide 227.

A feeding mechanism is provided for imparting a transverse feeding movement to the truing tool carrier 238 relative to the slide 237. This mechanism is preferably a nut and screw type feeding mechanism comprising a feed screw 242 formed on the upper end of the carrier 238. A rotatable feed nut 243 meshes with or engages the feed screw 242 and is rotatably supported relative to the slide 227.

A feeding mechanism 244 is provided for actuating the feed nut 243 by and in timed relation with the longitudinal movement of the slide 227. This mechanism comprises a gear 245 which is keyed to the feed nut 243. A small gear 246 meshes with the gear 245 and is rotatably supported by a pawl actuating arm 248 which is rotatably supported on a hub portion of the gear 245. The gear 246 serves as a pawl to actuate the gear 245. The gear 246 is connected by a one-way ball clutch 249 which is

supported by a shaft 249*a* (Fig. 15). The gear 246 is arranged to rotate freely in a counter-clockwise direction. When the slide 227 moves longitudinally toward the right (Fig. 13), a lug 250 formed integral with the arm 248 moves into engagement with an adjustable stop screw 251 which serves to impart a counter-clockwise movement to the arm 248 during which movement the ball clutch 249 holds the gear 246 against rotary motion so that a rotary motion is imparted to the gear 245 thereby imparting a rotary motion to the feed nut 243 to cause a predetermined downward feeding movement to the carrier 238 and the truing tool 239.

When the slide 227 moves toward the left, the lug 250 moves away from the stop screw 251 and the released compression of a spring 252 returns the arm 248 to a central position. When the slide approaches the left hand end of its stroke, a cam face 253 formed integral with the arm 248 moves into engagement with an adjustable stop screw 254 which causes a counter-clockwise rotary motion to be imparted to the arm 248 so that the gear 246, being locked against rotation by ball clutch 249, to impart a rotary motion to the gear 245 thereby imparting a predetermined downward feeding movement to the carrier 238 and the truing tool 239. It will be readily apparent from the foregoing that a down feeding movement of the truing tool 239 is obtained at each end of the movement of the slide 227. The down feed at the left hand end of the movement of the slide serves to position the truing tool for the next truing cycle. The down feed at the right hand end serves to position the truing tool before the return stroke of the truing tool 239 toward the left. The amount of down feed of the truing tool at each end of its stroke may be varied, as desired, by manipulation of the stop screws 251 and 254.

A reversing valve 255 is provided for controlling the admission to and exhaust of fluid from the truing tool cylinder 229. The valve 255 is a piston type valve comprising a valve stem 256. In the position illustrated in Fig. 16, fluid under pressure from the pipe 90 enters a valve chamber 257 and passes through a pipe 258, through a throttle valve 259 into a cylinder chamber formed at the right hand end of the cylinder 229 to cause the piston 230 together with the slide 227 to move toward the left. During this movement, fluid within the cylinder chamber at the left hand end of the cylinder 229 exhausts through a pipe 260, through a throttle valve 261, through a central passage in the reversing valve 255 and exhausts through a pipe 262 into the reservoir 89. A spring pressed ball 263 serves to normally hold the valve 255 against endwise motion. The valve 255 is actuated toward the right mechanically and toward the left by fluid under pressure.

As illustrated in Fig. 13, the slide 227 is provided with a bracket 264 having an adjustable actuating screw 265 which is axially aligned with the valve stem 256 so that when the slide 227 moves toward the right, the screw 265 will engage the end of the valve stem 256 and shift the valve stem 256 toward the right of the position illustrated in Fig. 16. This arrangement has been illustrated diagrammatically in Fig. 16 by an arm 266 which is connected to move with the piston rod 231.

A pipe 268 is connected to the right hand end of the valve 255. When fluid under pressure is passed through the pipe 268, fluid enters an end chamber at the right hand end of the valve 255 and shifts the valve stem 256 toward the left so as to reverse the flow of fluid between the valve 255 and the cylinder 229. When the valve 255 is in a left hand end position, fluid entering the valve chamber 257 is passed through the throttle valve 261 and also through a ball check valve 269 into the cylinder chamber formed at the left hand end of the cylinder 229 to move the piston 230 together with the slide 227 longitudinally toward the right.

When pressure is passed to the left hand end of the cylinder 229, it also passes through a pipe 270 into the right hand end of a cylinder 271 of a wheel feed compensating mechanism to be hereinafter described. The cylinder 271 contains a slidably mounted piston 272 which is fastened to the right hand end of a piston rod 273 (Fig. 16). A compression spring 274 surrounds the piston rod 273 and is interposed between the piston 272 and a left hand end cap 275 on the cylinder 271. The function of this compensating cylinder will be hereinafter described.

A control valve 280 is provided to facilitate interlocking the truing apparatus with the table indexing movement. This valve is a piston type valve comprising a valve stem 281. A compression spring 282 is provided normally to hold the valve 280 in a right hand end position. When the slide 227 is traversed toward the left, an adjustable actuating screw 283 carried by the bracket 232 engages the end of the valve stem 281 and shifts the valve 280 into a left hand end position as illustrated in Fig. 16. The actuation of the valve 280 is shown diagrammatically in Fig. 16 in which a bracket 284 carried by the piston rod 231 serves to engage the valve stem 281 to shift the valve 280.

A manually operable selector valve 285 is provided to facilitate automatic actuation of the wheel truing mechanism in timed relation with the grinding cycle, or a continuous reciprocation of the truing tool, or to render the truing apparatus inoperative as desired. The selector valve 285 has been illustrated diagrammatically in Figure 16 in a spread out view which shows three sections through the various valve passages. In the position of the selector valve 285 (Fig. 16) when fluid under pressure is passed through a pipe 286, it passes through a passage 287 in the selector valve 285 to shift the reversing valve 255 into a left hand end position thereby starting a truing cycle. The truing tool 239 together with the slide 227 is normally in a left hand end position and when a truing operation is initiated, the truing tool 239 together with the slide 227 makes one complete reciprocation, that is, to pass the truing tool across the operative face of the grinding wheel 34 twice.

If a continuous actuation of the truing tool is desired, the selector valve 285 is turned in a counter-clockwise direction so that fluid under pressure passing through the pipe 90 enters a valve chamber 288, passes through a pipe 289, through a passage 290 in the selector valve 285 and passes through the pipe 268 into the right hand end of the valve 255 to hold the valve 255 in a left hand end position. In this position of the parts, fluid under pressure passing through the pipe 90 enters the valve chamber 257 and passes into the left hand end of the cylinder 229 to traverse the truing tool 229 together with the slide 227 toward the right. As soon as this movement is started, the actuating screw 285 (Fig. 13) moves away from the valve stem 281 so that the released compression of the spring 282 shifts the valve 280 toward the right thereby cutting off fluid under pressure from the pipe 90 so that it cannot enter the valve chamber 288. The selector valve 285 in this position, fluid within the chamber at the right hand end of the valve 255 may exhaust through the pipe 268, through the passage 290 in the selector valve 285, through the left hand end chamber of the valve 280 and exhausts through the pipe 262. The movement of the truing tool slide 227 toward the right continues until the stop screw 265 (Fig. 13) engages the valve stem 256 and shifts it toward the right. When the valve 255 reaches a right hand end position, fluid under pressure from the pipe 90 entering the valve chamber 237 in the valve 255 passes through the pipe 258, through the throttle valve 259 into a cylinder chamber at the right hand end of the cylinder 229 (Fig. 16) a start a traversing movement of the truing tool slide 227 toward the left. Movement of the truing tool slide 227 toward the left continues until the stop screw 283 engages the valve stem 281 and shifts the valve 280 toward the left thereby

allowing fluid under pressure to pass through the pipe 268 into the right hand end chamber of the valve 255 to shift it into a left hand end position. It will be readily apparent that the valve 255 is shifted to the right hand end of the reciprocate stroke of the truing tool slide 227 and the valve 280 is shifted at the left hand end of the stroke of the truing tool slide 227 so that the truing tool slide reciprocates continuously to transverse the truing tool across the operative face of the grinding wheel as long as the selector valve 285 remains in the above mentioned position. The truing apparatus slide 227 reciprocates continuously to traverse the truing tool 239 across the operative face of the grinding wheel 34. The continuous truing operation continues as long as the selector valve 285 is positioned so that fluid may pass from the valve 280 through the passage 290. When it is desired to stop the continuous truing operation, the selector valve 285 is turned to the position illustrated in Fig. 16.

When it is desired to render the truing apparatus inoperative, the selector valve 285 is rotated so that fluid may exhaust from the right hand end chamber of the valve 255, through the pipe 268, through a passage 291 in the selector valve 285 and exhausts through a pipe 292. In this position of the selector valve, fluid under pressure is maintained in the chamber formed at the right hand end of the cylinder 229 to hold the slide 227 together with the truing tool 239 in a left hand end position.

A wheel spindle reciprocating mechanism is provided within the wheel slide 30 for reciprocating the wheel spindle 33 axially within its bearings during a grinding operation. This mechanism has not been illustrated since it is identical with that shown in the prior U. S. Patent No. 2,237,496 to G. T. Muskovin dated April 8, 1941, to which reference may be had for details of disclosure not contained herein. It is desirable to automatically stop the reciprocation of the grinding wheel spindle 33 during a truing operation. This is preferably accomplished by a hydraulically operated mechanism, shown diagrammatically in Fig. 16. At the start of a truing cycle, when the valve stem 281 of the valve 280 moves toward the right, fluid under pressure from the pipe 90 entering the valve chamber 288 may pass through a pipe 295, through a throttle valve 296 into a cylinder chamber 297 formed in the left hand end of a cylinder 298. The cylinder 298 contains a slidably mounted piston 299 which is connected to one end of a piston rod 300. A compression spring 301 surrounding the piston rod 300 and interposed between the piston 299 and the right hand end of the cylinder 298 serves normally to hold the piston 299 in a left hand end position so as to facilitate an axial reciprocation of the wheel spindle during a grinding operation. When fluid under pressure is admitted to the cylinder chamber 297, the piston 299 is moved toward the right so that the piston rod 300 operates to render the wheel spindle reciprocating mechanism inoperative during a grinding wheel truing operation.

When a manual feeding adjustment of the truing tool 239 is desired, the selector valve 285 is rotated in a counter-clockwise direction (Fig. 16) so that fluid in the pipe 268 may exhaust through the passage 291. During normal operation of the truing apparatus, the ball clutch 249 is clamped in a fixed relationship with the arm 248 by means of a sleeve 305 and a threaded screw 306 having an actuating handle 307. When it is desired to manually feed the truing tool 239, the handle 307 is turned to release the nut 306 and the sleeve 305 thereby unclamping the ball clutch 249 from the arm 248. A manually operable feed wheel 308 may then be rotated. The feed wheel 308 is mounted at the lower end of a rotatable shaft 309 (Fig. 14) the upper end of which is provided with a gear 310 which meshes with the feed gear 245. A serrated wheel 311 together with a spring pressed plunger 312 are provided to hold the gear 310 against rotary motion except when actuated by the arm 248 or the manual feed wheel 308. It will be readily apparent from the foregoing disclosure that a rotary motion of the feed wheel 308 will be imparted to cause a vertical adjustment of the truing tool 239 together with the carrier 238. The direction of rotation of the feeding wheel serves to determine whether an up or a down feeding adjustment of the truing tool 239 is obtained.

A wheel feed compensating mechanism is provided automatically to advance the grinding wheel slide by an amount equal to the down feed of the truing tool 239 at each actuation thereof. This mechanism comprises a vertically arranged shaft 315 which is rotatably supported on the wheel slide 30. The lower end of the shaft 315 is provided with a worm 316 which meshes with a worm gear 317 formed on the outer periphery of the feed nut 46. The upper end of the shaft 315 (Fig. 11) is supported by anti-friction bearings 318 which are supported in fixed relationship with the wheel slide 30. A gear 319 is keyed onto the upper end of the shaft 315. An oscillatable pawl carrying arm 320 is rotatably supported by a bearing 314 on the upper end of the shaft 315. A gear 321 (Fig. 11) keyed onto a stud 322 which is rotatably supported on the arm 320 meshes with the gear 319. A one-way ball clutch 323 is interposed between the arm 320 and the stud 322 so that the gear 321 is arranged to rotate freely on the arm 320 when the arm is moved in a counter-clockwise direction so that the gear 321 rolls idly on the gear 319. The ball clutch 323 is arranged so that when the arm 320 (Fig. 10) is moved in a clockwise direction, the gear 321 is locked to the arm 320 and thereby imparts a rotary motion to the gear 319.

The gear 321 together with the stud 322 and the ball clutch 323 are preferably supported by a pivotally mounted bracket 324 which is pivotally connected to the arm 320 by means of a stud 325. An adjusting screw 326 is provided to facilitate adjusting the meshing of the gear 321 relative to the gear 319. A clamping screw 327 is provided to facilitate locking the bracket 324 in adjusted position relative to the arm 320.

An adjustable stop screw 328 is provided on a bracket 329 which is fixedly mounted relative to the wheel slide 30. The stop screw 328 serves to limit the stroke of the arm 320 in a clockwise direction thereby limiting the compensating feed of the wheel slide. It will be readily apparent from the foregoing disclosure that by manipulation of the stop screw 328 the extent of compensating feed may be varied as desired so that the grinding wheel slide 30 will be advanced by an amount equal to the down feed of the truing tool 239. The piston rod 273 (Fig. 10) is connected by a stud 330 with one end of a link 331. The other end of the link 331 is connected by a stud 332 with the pawl arm 320. When fluid under pressure is passed through the pipe 270 to start a traversing movement of the truing tool 239 toward the right, fluid will be passed into a cylinder chamber formed at the right hand end of the cylinder 271 to move the piston 272 toward the left (Fig. 10) against the compression of the spring 274 thereby rocking the pawl arm 320 in a clockwise direction to transmit a compensating rotary motion to the feed nut 46. A single compensating adjustment of the wheel feeding mechanism is made at the start of each truing cycle. The amount of compensating feed is equal to the sum of the down feed at the right hand end of the truing tool stroke and at the left hand end thereof.

A holding pawl mechanism is provided to prevent counter-clockwise motion of the compensating feed gear 19. This mechanism comprises a small gear 335 which meshes with the gear 319 (Figs. 10 and 11). The gear 335 is keyed onto a stud 336 rotatably supported by a bracket 337 which is fixedly mounted relative to the wheel slide 30. A one-way ball clutch 338 is interposed between the stud 336 and bracket 337 which is arranged to allow the gear 335 to rotate freely in a counter-clockwise direction when the feed gear 319 is rotated to impart a compensating feed to the wheel slide. The one-way clutch

338 serves to lock the gear 335 to the bracket 337 so that the gear 319 cannot be rotated in a counter-clockwise direction. It will be readily apparent from the foregoing disclosure that the gear 335 serves as a holding pawl to facilitate rotation of the gear 319 in one direction only.

A control valve unit 350 is provided comprising a fluid operated reversing valve 351 which controls the direction of movement of the work table 11, a fluid actuated control valve 352 which serves to control the admission of fluid to and from the wheel feed and rock bar cylinders and also serves as a backlash eliminator valve for the wheel feed, and a fluid operator control valve 353 which serves to provide a rock bar dwell and also a table cushioning. The reversing valve 351 (Fig. 16) is a fluid pressure operated valve which is normally held in a central or neutral position by a pair of balanced compression springs in the opposite ends thereof.

When fluid under pressure is passed through a pipe 354 which enters an end chamber 355 in the valve 351 to shift the valve into a right hand end position. In this position of the valve 351 fluid under pressure from the pipe 90 enters a valve chamber 356 and passes out through a pipe 357 into a cylinder chamber 358 formed at the right hand end of the table cylinder 16 to start movement of the table 11 toward the right. During this movement of the table 11 fluid within a cylinder chamber 359 exhausts through a pipe 360, through a throttle valve 361 by means of which the rate of movement of the table toward the right may be regulated. Fluid passing through the throttle valve 361 passes through a pipe 363. A ball check valve 362 is provided between the pipe 360 and the pipe 363 so that when fluid under pressure is passed through the pipe 363 to cause a movement of the table 11 toward the left, fluid may pass substantially unrestricted through the ball check valve to facilitate a rapid movement of the table 11 during its idle stroke.

Fluid exhausting through the pipe 363 enters a valve chamber 364 in the valve 351 and passes out through a pipe 365 into a valve chamber 366 in the valve 352. Fluid entering the valve chamber 366 passes out through a pipe 367, through a ball check valve 368 and exhausts through a pipe 369. This allows the table 11 to travel at a normal indexing rate as controlled by the throttle valve 361. When the valve 353 is shifted toward the right as will be hereinafter described, the pipe line 367 is cut off so that fluid exhausting into the chamber 366 must exhaust through a pipe 370 and through a throttle valve 371, through the ball check valve 368 and exhausts through the pipe 369. This throttling arrangement serves to provide a slow-down in the indexing movement of the table 11 as it approaches the next grinding position.

When fluid under pressure is passed through the pipe 354 then into the end chamber 355 to shift the valve 351 toward the right, fluid passes through both a throttle valve 372 and a ball check valve 373. Fluid within a right hand end chamber 374 in the valve 351 exhausts through a throttle valve 375, through a pipe 376. A ball check valve 377 is provided between the end chamber 374 and the pipe 376 which serves to allow substantially unrestricted flow of fluid under pressure from the pipe 376 into the end chamber 374 when fluid under pressure is reversed.

A manually operable table actuated rotary-type reversing valve 380 is provided for controlling the direction of flow of fluid through the pipe 354 and the pipe 376. The valve 380 comprises a valve rotor 381 which may be actuated manually by means of a control lever 382 or actuated automatically by a pair of adjustable table dogs 383 and 384 which are adjustably mounted on the work table 11. When the table 11 moves toward the right and approaches its extreme end position, the dog 383 engages a lug 385 which is fixedly mounted relative to the valve rotor 381 to shift the valve rotor 381 in a counter-clockwise direction. Similarly at the other end of the table stroke as the table approaches its left hand end position, the table dog 384 engages a lug 386 fixedly mounted relative to the valve rotor 381 to rock the valve rotor 381 in a clockwise direction into the position illustrated in Fig. 16.

The mechanism above described for actuating the reversing valve 380 is diagrammatically shown in Fig. 16. As shown in Fig. 6, the lever 380 is mounted at the upper end of a vertically arranged rotatable shaft 390. A short lever arm 391 is mounted on the lower end of the shaft 390. The arm 391 is connected by a stud 392 with one end of a link 393. The other end of the link 393 is connected by a stud 394 with a snap-over or load and fire mechanism 395 to actuate the rotor 381 of the valve 380. When the table 11 reaches the right hand end of its stroke, the dog 383 engages the lug 385 to rock the reversing lever 382 in a clockwise direction (Fig. 7) which serves through the mechanism above described to impart a rotary motion to the valve rotor 381 in a counter-clockwise direction (Figs. 6 and 16) during which movement the load and fire mechanism 395 engages an actuating roller 396 of a normally closed limit switch LS6 to open the switch. The function of the switch LS6 will be hereinafter described.

An interlock is provided so that the table indexing movement cannot be started until the rock bar 20 is rocked to an inoperative position to separate the master cams 100 from the follower roller 101. This interlock preferably comprises a piston type valve 400 (Fig. 16) having a valve piston 401 which is normally held in an uppermost position by a compression spring 402. The valve stem 401 is provided with a pair of spaced integral valve pistons which form a valve chamber 403. The rock bar 20 is provided with an arm 404 which is arranged to engage and depress the valve stem 401 into the position illustrated in Fig. 16 when the rock bar 20 is rocked to an inoperative position.

A pipe 405 is connected between the pipe 140 and the valve 400. Similarly a pipe 406 is connected between the pipe 137 and the valve 400. A pipe 407 is connected between the valve 400 and a cycle start valve 410 to be hereinafter described. The valve 400 (Fig. 16) is shown depressed by the arm 404 since the rock bar 20 is rocked to an operative position. The rock bar is also provided with an arm 408 (Fig. 16) which is arranged to open a normally closed limit switch LS3 when the rock bar 20 is rocked to an inoperative position. The rock bar 20 is also provided with an adjustable arm 408*a* (Figs. 16 and 18) which is arranged to actuate a limit switch LS2 during each oscillation of the rock bar 20. The limit switch LS2 is operatively connected to impart an impulse to the electric counter or counters.

In the grinding of cams on a cam shaft, it may be desired to separate the cam being ground from the grinding wheel when the nose of the cam is in contact with the grinding wheel so that any mark on the cam caused by the separating movement will occur on the nose of the cam. In such a case a normally closed limit switch LS2 (Fig. 16) may be employed which is opened when the nose of the master cam approaches engagement with the follower roller which serves at count-out of the electric counter to separate the grinding wheel from the cam being ground when the nose or high point of the cam being ground is in contact with the grinding wheel.

Similarly in the grinding of cams, some users may prefer to have the cam being ground and the grinding wheel separate on the base circle of the cam being ground so that any mark left due to the separating movement will occur on the base circle of the cam. In this case the normally closed limit switch as shown in Fig. 16 is replaced by a normally open limit switch LS2 (Fig. 18) which is actuated by the arm 408*a* each time the base circle of the cam approaches engagement with the master cam roller so that at count-out of the electric counter the separation of the grinding wheel from the cam being ground will oc-

cur when the base circle of the cam being ground is in contact with the grinding wheel.

In case it is desired to separate the cam being ground from the grinding wheel when the nose or high point of the cam is in engagement with the grinding wheel, the normally closed limit switch LS2, as shown in Fig. 16 is utilized to control the actuation of the count coils of the counters 481 and/or 482 to control the operation of the wheel and work. In case this set-up is utilized fluid under pressure from the valve chamber 486 of the valve 352 passes through the passage 487, through the ball check valve 503 through a throttle valve 499*a* and through the pipe 84 into the cylinder chamber 83 rapidly to move the piston toward the left to move the grinding wheel rapidly to an inoperative position. At this time the valve 353 is in a right hand end position and gradually moves toward the left as controlled by the throttle valve 452. As soon as the port at the end of the passage 487 is uncovered fluid under pressure from the valve chamber 486 passing through the passage 487 enters the valve chamber 488 in the valve 353 and passes through the pipe 137 to the cylinder chamber 138 to move the piston 126 toward the right into the position illustrated in Fig. 16 thereby rocking the rock bar 20 to an inoperative position. In this case the movement of the rock bar to an inoperative position is delayed in its action and the delay thereof may be regulated and controlled by manual adjustment of the throttle valve 452. With this arrangement of the parts, the grinding wheel is rapidly separated from the cam being ground while the nose of the cam is in operative engagement therewith after which the rock bar 20 is rocked to an inoperative position.

A ball check valve 503*a* is connected in the pipe line 84 between the ball check valve 503 and the cylinder 75. A bypass around the ball check valve 503*a* is provided which is controlled by a manually operable valve 499*a*. A pipe 137*a* is connected between the pipe 137 and the pipe 84. A ball check valve 503*b* is provided in the pipe line 137*a* so that fluid may pass only in the direction toward the cylinder 75. A shut-off valve 499*b* is provided in the pipe line 137*a* between the pipe 137 and the ball check valve 503*b*. When the separation of the cam and grinding wheel is controlled as above described, the valve 499*b* is closed and the valve 499 opened so that fluid under pressure may pass around the ball check valve 503 into the cylinder chamber 83.

In case it is desired to separate the grinding wheel from the cam being ground while the base circle of the cam is in operative engagement therewith, a normally open limit switch LS2 is provided such as shown in Fig. 18. With this set-up the valve 499*b* is opened and the valve 499*a* is closed so as to cause a delayed action in the flow of fluid through the pipe 137 to both the cylinder 75 and the rock bar cylinder 125. The extent of the delayed action of fluid passing through the pipe 137 may be regulated by adjustment of the throttle valve 452 which controls the rate of shifting movement of the valve 353 toward the left. In this latter case the normally open limit switch LS2 is arranged so that the bracket 408*a* on the rock bar 20 actuates the limit switch LS2 slightly before the base circle of the master cam rotates into contact with the follower roller 101 so that at count-out of the counters 481 and 482, the separating movement between the grinding wheel 34 and the work piece 27 will be initiated so as to cause a simultaneous movement of the rock bar 20 and the feed piston 76 to separate the cam being ground from the grinding wheel when the base circle of the cam is in operative engagement with the grinding wheel.

The cycle start valve 410 is a piston type valve comprising a valve stem 411 having a pair of spaced integral valve pistons 412 and 413 which form a valve chamber 414. The valve 410 is normally held in an uppermost position by means of a compression spring 415 (Figs. 6 and 16).

A cycle start lever 416 is mounted on the upper end of a vertical shaft 417 supported in bearings 418 and 419. The lower end of the shaft 417 is provided with a short arm 420 which is provided with an offset stud 421 which is arranged to engage a frusto-conically shaped head 422 mounted on the upper end of a plunger 423 for actuating the valve stem 411.

The lever 416 is provided with a horizontally projecting stud 424 which is arranged in the path of a stop dog 425 adjustably supported on the table 11. The control lever 416 is slidably supported on the upper end of the shaft 417 and is normally held in a downward position (Fig. 6) by a compression spring 426. When the table 11 moves toward the right hand end of its idle stroke after grinding all of the cam on a cam shaft, the stud 424 rides up a cam slope 427 formed on the stop dog or loading dog 425. After the stud 424 rides over the dog the compression of the spring 426 causes a downward movement of the lever 416 so that the stud 424 drops in back of the stop dog 425. The table 11 continues a slight distance toward the right until the reversing dog 384 reverses the direction of movement of the table causing it to start movement toward the left which continues until the stop or loading dog 425 imparts a rotary motion to the stop lever 416 to rotate the shaft 417 so that the stud 421 rides up the frusto-conical face 422 to depress the valve stem 411 to position the valve in the positions illustrated in Figs. 6 and 16 thereby stopping the cycle of the machine.

In the position of the valve 410 (Figs. 6 and 16), fluid under pressure passing through the pipe 407 is blocked by the valve piston 412. When it is desired to start a cam grinding cycle, the start lever 416 is raised slightly and rotated in a counter-clockwise direction (Fig. 7) thereby releasing the compression of the spring 415 to cause an upward movement of the valve stem 411. In this position of the valve 410 fluid under pressure in the pipe 407 may pass through the valve chamber 414 and through a pipe 428 (Fig. 16) to the table actuated reversing valve 380. In the position of the valve 380 (Fig. 16) fluid from the pipe 428, passes through a chamber in the valve 380 and through the pipe 354, through both the throttle valve 372 and the ball check valve 373 into the end chamber 355 of the valve 351 to shift the valve 351 into a right hand end position. In this position of the valve fluid under pressure from the pipe 90 enters the valve chamber 356 and passes out through the pipe 357 into the cylinder chamber 358 to start a longitudinal movement of the table 11 toward the right.

A table indexing mechanism is provided for successively locating the table 11 in predetermined positions for grinding successive cams on a cam shaft to be ground. This mechanism may comprise a table stop lug 430 fixedly mounted on a pivotally mounted lever 431 which is supported by a stud 432. The stud 432 is supported in fixed relation with the base 10. A compression spring 433 serves normally to exert a pressure tending to hold the stop lug 430 in an uppermost position. The stop lug 430 is arranged in the path of a plurality of adjustable table dogs 434 carried by the table 11 intermittently and successively to locate the table in positions for grinding cams.

A hydraulically operated mechanism is provided for rocking the arm 431 to shift the stop lug 430 out of the path of table dogs 434 to facilitate an indexing movement. This mechanism may comprise a vertically arranged plunger 435 (Figs. 6 and 16) which is provided with a lip 436 which is arranged to engage a portion of the lever 431. A hydraulic cylinder 437 contains a slidably mounted piston 438 which is connected to one end of a piston rod 439. The other end of the piston rod 439 is connected to the plunger 435 to move it vertically in a manner to be hereinafter described. A compression spring 433 serves normally to hold the stop lug in an uppermost position in the path of the table dogs 434.

When fluid under pressure is passed through a pipe 441, it enters a cylinder chamber below the piston 438 and assists the spring 440 in holding the plunger 435 in an uppermost or operative position. When fluid under pressure is passed through a pipe 442 into a cylinder chamber formed at the upper end of the cylinder 437, the piston 438 together with the piston rod 439 and the plunger 435 moves downwardly to rock the lever 431 in a counter-clockwise direction thereby swinging the stop lug 430 out of the path of the table dogs 434.

A slow-down mechanism is provided whereby the indexing movement of the table 11 may be slowed down just before the table dog 434 moves into engagement with the stop lug 430. This mechanism comprises a vertically arranged plunger 445 which slides within a central bore within the plunger 435. The plunger 445 is arranged to actuate a piston type valve 446 (Figs. 6 and 16) which comprises a valve stem 447 having a pair of spaced valve pistons 448 and 449 formed integrally therewith so as to form a valve chamber 450. A compression spring 451 serves normally to hold the valve stem 447 together with the plunger 445 in an uppermost position with its upper end positioned in the path of the table dogs 434.

A cycle control valve 455 is provided for controlling the admission to and exhaust of fluid from the cylinder 437. The valve 455 is a piston type valve comprising a valve stem 456 having a plurality of valve pistons formed integrally therewith to form a plurality of spaced valve chambers 457, 458 and 459 (Fig. 16). A compression spring 460 serves normally to exert a pressure tending to move the valve stem 456 into a right hand end position. A solenoid S1 is provided which when energized serves to shift the valve stem 456 into a left hand end position as illustrated in Fig. 16. In the position of the parts illustrated in Fig. 16 fluid within the chamber at the upper end of the cylinder 437 may exhaust through the pipe 442 into the valve chamber 459 and out through an exhaust pipe 461. In this position of the parts fluid under pressure from the pressure pipe line 90 enters the valve chamber 458 and passes through the pipe 441 into the cylinder chamber at the lower end of the cylinder 437 to supplement the spring 440 so as to hold the piston 438 together with the plunger 435 in an uppermost position. At the same time fluid passing through the pipe 441 is conveyed to the valve 446 but is blocked by one of the valve pistons.

When the solenoid S1 is deenergized after a grinding cycle, the valve stem 456 moves toward the right so that fluid from the pressure pipe 90 entering the valve chamber 458 passes through the pipe 442 into the upper cylinder chamber in the cylinder 437 to cause a downward movement of the piston 438 together with the piston rod 439 and the plunger 435 thereby rocking the lever 431 (Fig. 6) in a counter-clockwise direction to withdraw the stop lug 430 out of the path of the table dogs 434 thereby initiating a table indexing movement to position the table 11 for grinding the next cam on the cam shaft to be ground.

The table 11 is indexed intermittently toward the right to grind successive cams on the cam shaft 27. After the last cam on the shaft has been ground, the table 11 continues its movement toward the right until the reversing dog 383 engages the detent 385 to shift the valve 380 into a reverse position. Before the valve 380 is reversed, a dog 465 (Fig. 1) on the table 11 actuates a limit switch LS5 to open the normally closed contacts thereof and to close the normally open contacts thereof, so that when the positioning cam 409 opens the normally closed limit switch LS4, the work driving motor 145 will stop with the cam shaft 27 in a predetermined loading position.

A push button start switch 470 (Fig. 17) is provided for starting an electric pump driving motor 474 which drives the fluid pumps 85 and 86 (Fig. 16) and at the same time serves to start a motor 475 to drive a coolant fluid pump (not shown). A push button stop switch 471 is provided to facilitate stopping the motors 474 and 475 when desired.

A push button start switch 472 is provided for starting the grinding wheel driving motor 35. A push button stop switch 473 is provided to facilitate stopping the motor 35 when desired.

A start switch 476 is provided for rendering the control mechanisms of the machine operative and a stop switch 477 is provided for stopping the operation of the machine at any time when desired. A pivotally mounted control lever 478 is provided for actuating the start switch 476 and the stop switch 477. The actuation of the lever 478 in a clockwise direction (Fig. 17) serves to close the start switch 476 to energize a relay switch CR2. A holding circuit is set up through one of the contactors of the relay switch CR2 to maintain relay switch CR2 energized. The function of the relay switch CR2 will be hereinafter described.

It is desirable to provide a work driving mechanism arranged so that the work piece may be first rough ground while rotating at a relatively fast speed after which the speed is automatically reduced to a slower finishing speed. The work driving motor 145 is preferably a two-speed motor in which the high speed windings are utilized to facilitate stopping the motor with the work piece or cam shaft 27 in a predetermined position to facilitate loading. The motor 145 is controlled by a fast speed relay switch FH to facilitate rotating the work at a rough grinding speed, and a relay switch SH to control the slow speed of the motor 145 for a finish grinding speed. A pair of electric counters 481 and 482 are provided, the counter 481 serving to control the duration of the first speed of the motor, and counter 482 serving to control the duration of the finish grinding speed of the motor 145 in a manner to be hereinafter described.

A selector switch 480 is provided which in the position illustrated in Fig. 17 serves to render both of the counters 481 and 482 operative so that the motor 145 drives the cam shaft 27 through a predetermined number of rotations at a rough grinding speed after which the speed of the motor 145 is automatically reduced to a finish grinding speed, the duration of which is controlled by the counter 482. The selector switch 480 as illustrated is positioned with contacts B closed so that both the counters 481 and 482 are rendered operative.

If it is desired to operate the machine as a rough grinding machine, the selector switch 480 is shifted in a counter-clockwise direction (Fig. 17) to close the contactor F which serves to render the counter 482 inoperative and the counter 481 operative to control the duration of the rough grinding operation, the speed of said motor being controlled in this case by relay switch FH. If it is desired to operate the machine as a finished grinding machine, the selector switch 480 may be shifted in a clockwise direction (Fig. 17) to close the contactor S which serves to render the counter 481 inoperative and the counter 482 operative to control the duration of the finish grinding operation during which the speed of the motor 145 is controlled by the relay switch SH.

A manually operable selector switch 485 is provided which as shown in Fig. 17 serves to render both of the counters 481 and 482 operative. If it is desired to cut out both of the counters 481 and 482, the switch 485 may be shifted in a clockwise direction, after which a manually operable start switch 486 may be operated to control the motor 145 manually to facilitate setting up the grinding machine.

The cam grinding machine is made ready for a grinding operation by turning the electric power on, after which a cam shaft 27 is loaded into the machine. The switch 470 is closed to start both the hydraulic pump motor 474 and the coolant fluid pump motor 475. The switch 472 is closed to start the wheel driving motor 35. The normally closed limit switch LS4 is opened by the positioning cam 409. The limit switch LS4 is connected

in series with the normally open limit switch LS5 operated by the table dog 465 which operates when the table indexes to position the last cam on the cam shaft 27 into an operative position for grinding. The normally closed limit switch LS6 is connected in series with the limit switch LS1 to prevent actuation of the valve 455 and thereby prevent movement of the table 11 toward the left before the rock bar 20 rocks to an inoperative position as illustrated in Fig. 16. The limit switch LS3 (normally closed) is held open by the rock bar 20 when in an inoperative position. During each oscillation of the rock bar 20 when the rock bar is in an operative position, the normally closed contacts of the limit switch LS2 open giving a count impulse to either of the electric counters 481 and 482. The normally closed limit switch LS1 is closed so that the solenoid S1 is energized and the clutch coils CCH1 and CCH2 of the counters 481 and 482 holds the solenoid S1 energized through the contacts LC1 or LC2 until count-out. When a table dog 434 depresses the plunger 445 the limit switch LS1 is opened. When the solenoid S1 is energized, the valve 455 is moved into a left hand end position so as to allow fluid under pressure to pass through the lower chamber of the cylinder 437 and also to the valve 446 which is now blocked. The table stop dog 425 has rotated the cycle start-stop lever 416 in a clockwise direction to depress the valve 410 so as to cut off fluid between valves 352—353—400 and the valves 380 and 351. The rocking bar 20 and the wheel slide 30 are held in inoperative positions by fluid under pressure through the valves 352 and 353. The wheel slide swivel cylinder 197 is balanced so that both sides thereof are open to the exhaust. The table stop lever 431 together with the stop lug 430 is held in an upper or operative position by fluid under pressure passing to the lower chamber in the cylinder 437 from the valve 455. The reversing lever 382 is in position for a right hand traversing movement of the table 11 but the table 11 is held stationary. Since there is no pressure on either side of the valve 351 which is held in a centered position by a pair of balanced compression springs. The valves 352 and 353 are normally held in a left hand end position by compression springs.

In the position of the valves 352 and 353 (Fig. 16) fluid under pressure from the pipe 90 enters a valve chamber 486 in the valve 352 and passes through a passage 487 into a valve chamber 488 in the valve 353 and passes through the pipe 137 into the cylinder chamber 138 to move the rock bar piston 26 toward the right into the position illustrated in Fig. 16 to rock the rock bar 20 to an inoperative position. During this movement fluid may exhaust from the cylinder chamber 139 through the pipe 140 into a valve chamber 489 in the valve 352, through a central passage 490 in the valve 352 into a valve chamber and out through an exhaust pipe 495.

The grinding wheel truing apparatus is preferably arranged so that when the work table reaches the end of its movement toward the right in grinding successive cams on the cam shaft, the shifting of the reversing valve serves to initiate an idle return stroke of the work table toward the left to a loading position. The truing apparatus is preferably arranged so that when the table reversing valve shifts to start the idle stroke of the table, the truing cycle is started. Due to the rapid idle stroke of the table, the truing apparatus which operates at a slow speed may not complete its truing cycle before the table reaches a loading position. It is desirable to provide a suitable interlock mechanism so that after the ground shaft has been replaced by a new shaft to be ground, a new grinding cycle cannot be initiated until the truing apparatus has completed its operation. After loading the new shaft into the machine, the cycle start-stop lever may be moved to initiate the next cycle of operation and the table will travel toward the right until it is stopped by the first table index dog 434 in position for grinding the first cam on the right hand end of the cam shaft. An interlock is provided between the grinding wheel truing apparatus and the wheel feed and rock bar actuating mechanism so that the rock bar cannot be moved to an operative position or an infeed of the grinding wheel initiated until the truing apparatus has completed its truing operation.

This is preferably accomplished by connecting the pipe 443 with a valve chamber 444 in the valve 280. A pipe 454 is connected between the valve chamber 444 and an end chamber 466 formed in the left hand end of the valve 352. When the truing apparatus has completed one complete reciprocation of the truing tool 239 across the operative face of the grinding wheel 34, the valve stem 281 is shifted toward the left into the position illustrated in Fig. 16 so that fluid under pressure from the valve 446 passes through a throttle valve 452 into an end chamber 497 to shift the valve 353 toward the right. Fluid within the pipe 443 also passes into the valve chamber 444 of the valve 280 and passes through the pipe 454 into the end chamber 466 formed at the left hand end of the valve 352 to shift the valve 352 into a right hand end position. In this position of the valve 352 fluid under pressure from the pipe 90 enters the valve chamber 489 of the valve 352 and passes through a pipe 491, through a throttle valve 492, through the pipe 140 into the cylinder chamber 139 to move the rock bar piston 126 toward the left (Fig. 16) thereby shifting the rock bar to an operative position with the master cam 100 in operative engagement with the follower roller 101.

At the same time fluid under pressure passing through the pipe 491 passes through a throttle valve 498, through the pipe 81 into the cylinder chamber 82 formed at the left hand end of the grinding wheel feed cylinder 75 to start the piston 76 moving toward the right so as to initiate an infeeding movement of the wheel slide 30 and the grinding wheel 34. By manipulation of the throttle valve 492, the rate of movement of the rock bar piston 126 toward the left may be varied as desired. Similarly by manipulation of the throttle valve 498 and a throttle valve 499, the rate of movement of the feed piston 76 toward the right may be regulated as desired. A ball check valve 503 serves to facilitate rapid admission of fluid to the feed cylinder 75 when the flow of fluid is reversed to cause a rearward movement of the wheel slide 30 and the grinding wheel 34.

Operation

The lever 478 is rocked in a clockwise direction (Fig. 17) to close a circuit thereby energizing a relay switch CR2. One set of contactors of the relay switch CR2 set up a holding circuit to maintain the switch energized. The other set of contacts of relay switch CR2 serve to render a circuit operative as will be hereinafter described.

When it is desired to start a grinding cycle the table cycle start-stop lever 416 is raised so that the stud 424 clears the stop dog 425 and is then rotated in a counterclockwise direction (Fig. 7) to allow the valve 410 to move upwardly under the influence of the released compression of the spring 415. This allows fluid under pressure to pass through the valve chamber 414 in the valve 410 to pass through the reversing valve 380 into the left hand end chamber 355 of the valve 351 to shift the valve 351 toward the right so that fluid under pressure passes through the pipe 357 to the cylinder chamber 358 to move the cylinder 16 and the table 11 toward the right. Fluid within the cylinder chamber 359 of the cylinder 16 exhausts through the throttle valve 361, through the pipe 363, through the valve chamber 364 in the valve 351, through the pipe 365 into the valve chamber 366 of the valve 353 and exhausts through the pipe 367, through the ball check valve 368, and through the exhaust pipe 369 into the reservoir 89.

The table 11 moves rapidly toward the right until the first table dog 434 depresses the plunger 445 which causes a downward movement of the valve 446 and also serves

to open the limit switch LS1. The solenoid S1 is held energized by the counter contacts LC2 and LC1. The valve 446 when depressed passes fluid under pressure through a pipe 443, through both a throttle valve 452 and a ball check valve 453 into a left hand end chamber 497 of the valve 353 to move the valve toward the right. During this movement, the port at the end of the pipe 367 is cut off so that fluid under pressure within the valve chamber 366 exhausts through the pipe 370, through the throttle 371, the ball check valve 368 and the exhaust pipe 369 into the reservoir 89. The throttle 371 serves to regulate the slow speed of the table 11 which continues until the first table dog 434 engages the stop lug 430 on the stop lever 431 to stop the table 11 in position for grinding the first cam on the cam shaft 27.

When the truing cycle for truing the grinding wheel has been completed, the valve 280 is shifted into the position illustrated in Fig. 16 so that fluid under pressure from the valve 446, now depressed, passes through the pipe 443 into the valve chamber 444 of the valve 280, through the pipe 454 into the end chamber 466 of the valve 352 to shift the valve 352 toward the right at a rate controlled by the throttle valve 467. When the valve 352 reaches its right hand end position fluid under pressure from the pipe 90 passes through the valve chamber 489 of the valve 352 and passes through the pipe 491, through the throttle valve 492, through the pipe 140 into the cylinder chamber 139 to move the rock bar piston 126 toward the left and thereby shift the rock bar 20 into an operative position. At the same time fluid passing through the pipe 491 passes through a throttle valve 498 into the cylinder chamber 82 to start the feed piston 76 moving toward the right to initiate an infeeding movement of the grinding wheel slide 30 and the grinding wheel 34.

Fluid under pressure from the valve 350 passing through the pipe 357 serves to maintain pressure within the table cylinder chamber 358 to maintain the dog 434 against the stop lug 430 of the lever 431.

When the valve 352 is shifted toward the right to pass fluid under pressure to initiate an infeeding movement of the grinding wheel, fluid within the feed cyinder chamber 83 exhausts substantially unrestricted through a pipe 500 into a valve chamber 501 in the valve 352 and out through the pipe 496 into the reservoir 89. This unrestricted exhaust of fluid from the cylinder chamber 83 serves rapidly to take up the backlash in the feed mechanism parts. Fluid may exhaust from the valve chamber 501 only during the passage of the chamber 501 across the port connected with the exhaust pipe 496. By manipulation of the throttle valve 467, the rate of movement of the valve 352 toward the right may be varied as desired so as to control the amount of exhaust fluid metered through the valve chamber 501. After the exhaust of fluid from the chamber 501 is cut off the remaining fluid exhausting from the feed cylinder chamber 83 passes through throttle valve 499 which controls the rate of infeeding movement of the grinding wheel during the grinding operation.

Fluid exhausting from the rock bar cylinder 125 exhausts through the valve chamber 488 of the valve 353 and out through an exhaust pipe 494 into the reservoir 89.

When the rock bar 20 rocks to an operative position for a grinding operation, the brackets or arms 408 and 408*a* rock in a counter-clockwise direction to allow the normally closed limit switches LS2 and LS3 to close. Through the normally closed contacts *a* of relay switch BH, now closed limit switch LS3, through the normally open contacts *b* of relay switch CR2 (now energized) serves to close a circuit to energize a time delay relay TR1. Current also passes through normally closed contacts *b* of relay switch CR3 and through the now closed contacts *a* of time relay TR1 to energize CR3 and to set up a holding circuit therefor. After a predetermined time interval elapses the contacts *a* of time delay relay TR1 open. When relay switch CR3 is energized current passes through one set of contacts *b* of switch CR3, through the selector switch 480 through contactors RC1 of the counter 481, through the normally closed contacts *f* of the relay switch SH to energize the relay switch FH to start the work drive motor 145 at a fast or rough grinding speed. The energizing of relay switch FH opens up the normally closed contactor of relay switch FH and thereby cuts out to break a circuit thereby rendering the counter coil ACH2 of the counter 482 inoperative. Another set of normally closed contacts *a* of the relay switch FH opens to break a circuit so as to prevent energization of the relay switch SH. The normally open contacts *f, g, h* of the relay switch FH close and the work rotates at a fast or rough grinding speed until the count coil ACH1 of the counter 481 counts-out breaks the contacts. At count-out, that is, after a predetermined number of oscillations of the rock bar, each of which actuates the limit switch LS2, the contacts RC1 of the counter 481 open and the contacts CC1 close. The opening of the contacts RC1 serve to deenergize the relay switch FH. The closing of the contactors CC1 serves through the contactor RC2 of the counter 482, through the selector switch 480, through one of the normally closed contacts *a* of the relay switch FH (now closed) to energize the relay switch SH. The closing of the normally open contacts *c, d, e* of relay switch SH serve to close circuits to reduce the speed of the motor 145 to a slow speed for a finish grinding speed. Grinding continues and at each actuation of the rock bar, the limit switch LS2 closes to actuate the count coil ACH2 of the counter 482. At the count-out, the contactors LC1, LC2 and RC2 open.

During the slow or final grinding speed of the work piece when the relay switch SH is energized power passes through the limit switch LS3, through the normally closed contacts of limit switch LS5, through the normally open (now closed) contacts *c* of relay CR3, through a normally open (now closed) contact *b* of relay switch SH to energize a transformer 505 which serves through a rectifier 506 to build up an electrical charge within a condenser 507. The charge built up in condenser 507 continues to build up until the counter 482 counts out to open contacts LC2 and RC2 to deenergize relay switch SH at which time the charge of energy within the condenser 507 instantly energizes a relay switch BH through normally closed contacts *a* of a relay switch SH which serves through a rectifier 508 to pass a direct current through the high speed windings of the motor 145 to provide a braking action to slow down and stop the rotation of the motor 145 when a cam has been ground to a predetermined extent. The energization of relay switch BH serves to open contacts *a* of relay switch BH to break the holding circuit to deenergize relay CR3 thereby rendering the circuit ready for the next cycle of operation.

It will be readily apparent from the foregoing disclosure that the work drive motor 145 is stopped when the rock bar 20 moves to an operative position. The closing of the limit switch LS3 during movement of the rock bar to an operative position serves in a manner above described to start the motor 145 at the fast or rough grinding speed. The motor 145 continues to rotate at the fast grinding speed until the work piece has rotated through predetermined number of rotations. During each rotation of the work piece, the rock bar operating a limit switch LS2 actuates the count coil ACH1 of the counter 481. At count-out the relay switch FH becomes deenergized and the relay switch SH energized to reduce the speed of the motor 145 to a slower or finish grinding speed. The finish grinding speed continues until the counter 482 counts out at which time the contacts LC1, LC2 and RC2 open thereby deenergizing S1 to shift valve 455 so as to cause wheel slide and rock bar to move to inoperative position. Movement of rock bar to inoperative position actuates LS3 so as to initiate a braking action as above described to stop the motor 145. The motor 145 remains stopped during the movement of the rock bar to an inoperative position and during the longi-

tudinal traversing movement of the table and remains in a stopped condition until the rock bar moves to an operative position for grinding the next cam on the cam shaft 27.

The opening of the contactors LC1 and LC2 of the counters 481 and 482 at count-out serves to break a circuit to deenergize the solenoid S1 to pass fluid under pressure to the upper chamber of the cylinder 437 to cause a downward movement of the plunger 435 to swing the stop lug 430 together with its supporting arm 431 in a counter-clockwise direction out of the path of the table dog 434 so as to start an indexing movement of the table 11.

When the counter 482 counts-out and LC2 and RC2 open, a circuit is broken to deenergize the solenoid S1 which allows the valve 455 to shift toward the right. When the valve 455 moves into a right hand end position it allows fluid under pressure to pass to the right hand end chambers of the valves 352 and 353 to move the valves toward the left (Fig. 16). Fluid under pressure is also passed to the cylinder 437 to pull down the table stop lug 430 and lever 431 which allows the table to move toward the right, providing the rock bar 20 has moved to an inoperative position as illustrated in Fig. 16. Movement of the rock bar 20 to an inoperative position serves to move the valve 400 downwardly. Fluid exhausting from the cylinder 437 passes through the valve 455. Fluid exhausts from the left hand end chamber of the valve 352 through the chamber 444 of the valve 280, through the valve 446, through the valve 455. Fluid exhausts from the left hand end chamber 497 of the valve 353, through a needle valve 452, through the valve 446 and through the valve 455 into the reservoir 89.

When the valve 352 moves into a left hand end position, that is, into the position illustrated in Fig. 16, fluid under pressure is passed to the cylinder 75 to move the wheel slide 30 together with the grinding wheel 34 to a rearward or inoperative position. In the position illustrated in Fig. 16 fluid under pressure passes through the valve chamber 488, through the pipe 137 into the rock bar cylinder chamber 125 to move the rock bar 20 to an inoperative position. During this movement the arm 408 carried by the rock bar 20 opens the limit switches LS2 and LS3. During movement of the rock bar to an inoperative position, the interlock valve 400 moves downwardly into the position illustrated in Fig. 16 to allow fluid under pressure to pass through the valve 410, through the table actuated reversing valve 380 to again move the valve 351 toward the right. Before the valve 400 moves downwardly, fluid exhausts from the end chamber of the valve 351 through the valves 380—410—400 and through the valve 352 into the chamber 490 and exhausts through pipe 496. It will be readily apparent from the foregoing that the pressure on the table cylinder 16 is momentarily removed to facilitate an easy withdrawal of the stop lug 430 and the lever 431. Fluid exhausts from the rock bar cylinder 125 through the valve 352 and exhausts through the pipe 496.

The cam grinding machine has been illustrated as set up for grinding cams having surfaces tapering in the opposite direction. At the start of the grinding operation, the wheel slide base 41 together with the wheel slide 30 are swiveled in a counter-clockwise direction with the stop lug 201 on the wheel slide base 41 engaging the stop screw 202 (Figs. 9 and 16). In this position of the parts the grinding wheel grinds a taper on the first cam at the right hand end of the cam shaft 27 tapering toward the headstock. When the table 11 is indexed longitudinally to position the second cam opposite the grinding wheel for a grinding operation, the swivel dog 219 depresses the valve stem 211 of the valve 210 so that fluid under pressure will pass through the valve 210 into the cylinder chamber 208 to move the piston 198 (Fig. 16) toward the right thereby swivelling the wheel slide base 41 together with the wheel slide 30 in a clockwise direction so that the stop lug 201 moves into engagement with the stop screw 203 thereby positioning the grinding wheel for grinding cam No. 2 with a surface tapering toward the footstock. As illustrated in Fig. 1 the cam No. 3 and cam No. 4 taper in a direction toward the headstock so that during the next two indexing movements of the table 11 the lever 215 rides off the dog 219 thereby releasing the compression of the springs 212 so that the wheel slide base is again returned to its normal position, that is, swiveled in a counterclockwise direction during grinding cams Nos. 3 and 4. The amount of taper produced on the cams is very slight, such as, for example a small fraction of a degree.

The cams Nos. 5 and 6 are illustrated as tapered toward the footstock. During the indexing movement of the table to position cams Nos. 5 and 6 for grinding, the relatively long dog 220 depresses the valve 210 so as to swivel the wheel slide base 40 and the grinding wheel slide 30 in a clockwise direction during grinding these two cams. Cam No. 7 (Fig. 1) is shown as tapering toward the headstock. During indexing movement to position the seventh cam for grinding, the dog 220 rides off the lever 215 and allows the valve 210 to move upwardly so that the wheel slide base swivels in a counterclockwise direction for grinding the seventh cam. The eighth cam on the shaft is shown as tapering toward the footstock. During the indexing movement of the table 11 to position the eighth cam opposite the grinding wheel, the dog 221 depresses the valve 210 to swivel the wheel slide base 41 in a clockwise direction to produce a surface on the eighth cam tapering toward the footstock. The dogs 219, 220 and 221 are adjustably positioned on the table 11 to correspond with the position of the table indexing dogs 434. If it is desired to grind straight faces on the cams of the cam shaft 27, the stop screws 202 and 203 (Figs. 9 and 16) may be adjusted so as to engage opposite sides of the lug 201 and so that the wheel slide base 41 is swivelled to a position so that the wheel spindle 33 is parallel to the axis of the cam shaft 27 to be ground. In such a grinding operation the wheel slide base remains in a fixed position.

As the table 11 moves toward the right, the dog 434 moves off the plunger 445. The released compression of the spring within the valve 446 causes an upward movement of the plunger 445 to cut-off the flow of fluid under pressure from the valve 455 so as to cut-off the flow of fluid under pressure to the valves 352 and 353. The upward movement of the plunger 445 closes the normally closed limit switch LS1 to energize the solenoid S1, also to energize the clutch coils CCH1 and CCH2 of the counters 481 and 482 respectively, also closes the holding circuit contacts LC1 and LC2 and the contacts RC1 and RC2. The energization of the solenoid S1 shifts the valve 455 toward the left in which position fluid is passed to the cylinder 437 to cause an upward movement of the plunger 435 to raise the arm 431 together with the stop lug 430 upwardly into an operative position into the path of movement of the next table index dog 434. The table continues its movement toward the right until the next table dog 434 again depresses the plunger 445 to cause a slowing down of the table before the stop lug 430 engages the dog 434 to stop the table in the proper position for grinding the next cam of the cam shaft 27. At the same time the dog 434 reaches a stop position to stop the indexing movement of the table, the wheel slide swivel dog 219 actuates the valve 210 to cause a swivelling movement of the wheel slide base 41 and the wheel slide 30 in a clockwise direction so that the second cam on the shaft will be ground with a tapering toward the footstock. The cycle of operation is repeated for each cam on the cam shaft to be ground with the wheel slide swivel mechanism operating in the manner above described.

After the last cam on the cam shaft 27 has been ground,

the table 11 moves a slight distance further toward the right until the reversing dog 383 engages the lug 385 to shift the reversing valve 380 into the reversing position. This allows fluid under pressure from the valve 410 to pass through the reversing valve 380 to move the valve 446 downwardly and also pass to the right hand end chamber 374 of the valve 351. Fluid under pressure from the reversing valve 380 also passes through the selector valve 285, through the pipe 268 into the right hand end chamber of the valve 255 which serves to pass fluid under pressure through the throttle valve 261 and the ball check valve 269, through the pipe 260 into the left hand end chamber of the cylinder 229 to initiate a wheel truing cycle by starting a traversing movement of the truing tool 239 toward the right. The downward movement of the valve 446 serves to open the limit switch LS1 thereby deenergizing the solenoid S1. The shifting movement of the reversing valve 380 into the reverse position actuates the load and fire mechanism 395 which opens the normally closed limit switch LS6. The deenergizing of the solenoid S1 shifts the valve 455 toward the right so that fluid under pressure is passed to the cylinder chamber formed at the upper end of the cylinder 437 to move the piston 438 together with the plunger 435 downwardly thereby rocking the stop lug 430 and its supporting lever 431 to an inoperative position where it remains during the entire movement of the table 11 toward the left.

Fluid under pressure is passed to the right hand end chamber 374 to shift the valve 351 toward the left so that fluid under pressure is passed through the pipe 363 into the cylinder chamber 359 to start a rapid traversing movement of the cylinder 16 together with the table 11 toward the left.

The grinding wheel is automatically trued during the idle stroke of the table 11 toward the left. When the valve 255 is shifted toward the left to pass fluid under pressure to the left hand end of the cylinder 229 to initiate a traversing movement of the truing tool toward the right, fluid under pressure is also passed through the pipe 270 into the cylinder chamber formed at the right hand end of the feed compensating cylinder 271 to impart a rotary motion to the feed nut 46 thereby feeding the wheel slide 30 and the grinding wheel 34 by an amount equal to the downfeed of the truing tool before the start of the truing cycle and at the end of the first pass of the truing tool across the face of the grinding wheel.

As the truing tool slide 227 approaches the right hand end of its stroke, the stop screw 251 engages the lug 250 to impart a down feeding increment to the truing tool 239 before the truing tool starts its return stroke toward the left. As the truing tool slide starts its stroke toward the right, the stop screw 283 moves away from the valve stem 281 thereby releasing the compression of the spring 282 which shifts the valve 280 toward the right. When the valve 280 is in its right hand end position fluid under pressure entering the valve chamber 288 passes through the pipe 295, through the throttle valve 296 into the cylinder chamber 297 to shift the valve piston 299 toward the right (Fig. 16) thereby shifting the piston rod 300 toward the right against the compression of the spring 301 to stop reciprocation of the grinding wheel spindle 33 during a wheel truing operation.

When the truing tool approaches the right hand end of its stroke, the stop screw 265 engages the valve stem 256 and shifts the valve 255 toward the right into the position illustrated in Fig. 16 thereby reversing the flow of fluid to the truing tool cylinder 229 to start a traversing movement of the truing tool 239 toward the left across the operative face of the grinding wheel 34. During this movement fluid exhausts from the left hand end chamber of the cylinder 229, through the valve 255 and out through an exhaust pipe 262 into the reservoir 89. At the same time fluid within the right hand end chamber of the cylinder 271 exhausts in the same manner through the pipe 262 so that the feed compensating mechanism resets itself under the released compression of the spring 274 for the next automatic feed compensation. As the truing tool slide approaches the left hand end of its stroke, the stop screw 254 engages the cam face 253 to impart a down feeding movement to the truing tool 239 to position the truing tool 239 for the next truing cycle.

At the end of the movement of the truing tool slide 227 toward the left, the valve 280 is shifted toward the left into the position illustrated in Fig. 16. In this position of the valve 280 fluid within the cylinder chamber 297 may exhaust through the throttle valve 296, through the pipe 295 and out through the exhaust pipe 262 into the reservoir 89 under the influence of the released compression of the spring 301 thereby starting reciprocation of the wheel spindle 33. The rate of traverse of the truing tool 239 both toward the right and the left is at a relatively slow speed as controlled by the throttle valves 259 and 261.

The idle stroke of the work table 11 toward the left is at a rapid rate so that before the truing tool 239 completes one complete reciprocation across the operative face of the grinding wheel 34, the work table 11 travels to the extreme left hand end position so that reversing dog 384 engages lug 386 to shift the reversing valve 380 in a clockwise direction into the position illustrated in Fig. 16 so that the pipe line 268 is connected to exhaust fluid through the valve 380 and through an exhaust pipe 510 into the reservoir 89. The valve 255 is, therefore, held in a right hand end position so that after the truing tool makes one complete reciprocation the truing tool stops. After the dog 383 shifts the reversing valve 380, the table 11 starts its movement toward the right until the table stop dog 425 engages the lug 224 and shifts the start-stop lever 416 in a clockwise direction (Fig. 7) so as to depress the valve 410 so that fluid under pressure to the reversing valves 380 is cut off to stop the table 11 in a loading position.

If it is desired to provide a manually controlled continuous reciprocation of the truing tool 239, the selector valve 285 is rotated in a counter-clockwise direction so that fluid under pressure may pass from the pipe 289, through the valve passage 290 into the pipe 268 to actuate the valve 255. In this position of the selector valve, the diamond or truing tool 239 will reciprocate continuously across the operative face of the grinding wheel until it is stopped by actuation of the selector valve 285. During this continuous truing operation, the truing tool will be fed downwardly by a predetermined increment at each end of the stroke of the diamond. Also at the start of the continuous truing operation each time the piston 230 starts moving toward the right (Fig. 16) a shot of oil under pressure will be passed through the pipe 270 to the feed compensating cylinder 271 to move the piston 272 toward the left to impart a compensating feeding movement to the feed nut 46 as above described.

If it is desired to render the truing apparatus inoperative, the selector valve may be turned so that the pipe 268 is connected through the passage 291 with an exhaust pipe 292 thereby preventing actuation of the valve 256 so that the truing apparatus is maintained inoperative.

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

We claim:

1. In a grinding machine having a longitudinally movable table, a rock bar on said table, a rotatable work

support including a master cam spindle having a plurality of cams which is mounted on said rock bar, a follower roller arranged to engage one of said cams, means including a two-speed motor to rotate said master cam spindle, means to control the fast speed of said motor during an initial grinding operation, means to control the slow speed of said motor during a final grinding operation, a counter for controlling the fast speed, means actuated by movement of the rock bar to an operative position to energize said counter, means actuated during each oscillation of the rock bar to impart an impulse to said counter to control the duration of the initial grinding speed, and a second counter to control said slow speed control means to control the duration of the final grinding speed, said first counter at count-out being operatively connected to energize said second counter to change from initial grinding to a final grinding speed, said second counter serving at count-out to initiate stopping the work drive motor after a grinding operation has been completed.

2. In a grinding machine having a longitudinally movable table, a rock bar on said table, a rotatable work support including a master cam spindle having a plurality of master cams which is mounted on said rock bar, a follower roller arranged to engage said master cams, means including a two-speed electric motor to rotate said master cam spindle, a relay switch to control the fast speed of the motor during a rough grinding operation, a relay switch to control the slow speed of said motor during a finish grinding operation, an electric counter to control the first relay switch, a limit switch actuated by movement of the rock bar to an operative position to energize said counter, a limit switch actuated during each oscillation of the rock bar to impart an impulse to said counter to control the duration of the rough grinding speed, a second electric counter to control said second relay switch to control the duration of the finish grinding speed, and operative connections between said counters arranged so that count-out of the first counter serves to energize the second counter to change from a rough to a finish grinding speed, said second counter serving at count-out to deenergize the slow speed relay switch to stop the work drive motor after a predetermined grinding operation has been completed.

3. In a grinding machine, as claimed in claim 2, in combination with the parts and features therein specified of a selector switch, and operative connections between said switch and each of said counters arranged so that when the switch is in one position the slow speed counter is rendered inoperative so that the work drive motor operates at a fast speed to facilitate setting up the machine as a rough grinding machine.

4. In a grinding machine as claimed in claim 2, in combination with the parts and features therein specified of a selector switch, and operative connections between said switch and each of said counters arranged so that when in one position the fast speed counter may be rendered inoperative so that the work drive motor is actuated only at a slow speed to facilitate setting up the machine as a finish grinding machine.

5. In a grinding machine, as claimed in claim 2, in combination with the parts and features therein specified of a selector switch and operative connections between said switch and each of said counters arranged so that when the switch is in one position both of the counters are rendered operative so that a work piece being ground is first rotated at an initial grinding speed and during the grinding operation the speed is automatically changed to a slow or final grinding speed.

6. In a grinding machine having a longitudinally movable table, a rock bar on said table, a rotatable work support including a master cam spindle having a plurality of master cams which is mounted on said rock bar, a follower roller arranged to engage master cams, means including a two-speed electric motor to rotate said master cam spindle, a relay switch to control the fast speed of said motor during a rough grinding operation, a relay switch to control the slow speed of said motor during a finish grinding operation, a counter to control said first relay switch, a limit switch actuated by movement of the rock bar to an operative position to energize said counter, a limit switch actuated during each oscillation of the rock bar to impart an impulse to said counter, a second counter to control said second relay switch, operative connections between said counters arranged so that count-out of the first counter serves to energize said second counter to slow-down said motor to finish grinding speed, means including a third relay switch operatively connected to supply a braking current to said motor, and operative connections between said second and third relay switches and said second counter so that at count-out of the second counter the slow speed relay is deenergized and work drive motor is rapidly stopped.

7. In a grinding machine having a longitudinally movable table, a rock bar on said table, a rotatable work support including a master cam spindle having a plurality of master cams thereon which is mounted on said rock bar, a transversely movable wheel slide having a rotatable grinding wheel, means including a fluid motor intermittently to index said table longitudinally in one direction to facilitate grinding a plurality of spaced cams on a camshaft, a table-actuated reversing valve to control the direction of movement of said table, and a truing apparatus mounted on the wheel slide including a longitudinally reciprocable truing tool, means including a fluid motor to traverse said truing tool longitudinally, a fluid actuated control valve therefor, and operative connections between the table reversing valve and said fluid actuated valve to initiate a truing operation by and in timed relation with actuation of the table reversing valve.

8. In a grinding machine having a longitudinally movable table, a rock bar on said table, a rotatable work support including a master cam spindle having a plurality of spaced master cams thereon which is mounted on said rock bar, a transversely movable wheel slide having a rotatable grinding wheel, means including a fluid motor to move said slide in either direction, a feed control valve therefor, means including a fluid motor intermittently to index said table longitudinally in one direction to facilitate grinding a plurality of spaced cams on a camshaft, a table actuated reversing valve to control the direction of movement of said table, a truing apparatus mounted on said wheel slide including a longitudinally reciprocable truing tool, means including a fluid motor to traverse said truing tool longitudinally, a fluid actuated reversing valve therefor, and an interlock valve actuated by and in timed relation with longitudinal reciprocation of the truing tool, and operative connections between said latter valve and the wheel feed control valve to prevent an infeeding movement of the grinding wheel before the truing tool has completed a truing cycle.

9. In a grinding machine having a longitudinally movable table, a rock bar on said table, a rotatable work support including a master cam spindle having a plurality of spaced master cams thereon which is mounted on said rock bar, a transversely movable wheel slide having a rotatable grinding wheel, means including a piston and cylinder to move said slide in either direction, a feed control valve therefor, means including a piston and cylinder intermittently to index said table longitudinally in one direction to facilitate grinding a plurality of spaced cams on a camshaft, a table-actuated reversing valve to control the direction of movement of said table, a truing apparatus mounted on said wheel slide including a longitudinally reciprocable truing tool, means including a piston and cylinder to traverse said truing tool longitudinally, a fluid operated reversing valve therefor, an interlock valve actuated by and in timed relation with the longitudinal reciprocation of the truing tool, and fluid connections between said latter valve and

the wheel feed control valve to prevent actuation of the feed control valve and an infeeding movement of the grinding wheel before the truing tool has completed a truing cycle.

10. In a grinding machine having a longitudinally movable table, a rock bar on said table, a rotatable work support including a master cam spindle having a plurality of spaced master cams which is mounted on said rock bar, an indexable follower roller associated therewith, means including a motor to rotate said master cam spindle, means including a fluid motor intermittently to index said table longitudinally in one direction to facilitate grinding a plurality of spaced cams on a camshaft, means including a fluid motor to move said rock bar to and from an operative position, a transversely movable wheel slide having a rotatable grinding wheel, means including a fluid motor to feed said slide in either direction, and a control valve unit including a fluid actuated reversing valve to control the table motor, a fluid actuated control valve simultaneously to control the rock bar motor and the wheel slide motor, a table-actuated reversing valve to control said fluid actuated reversing valve, reversing dogs on said table to actuate said table actuated reversing valve, a table actuated valve to control said fluid actuated control valve, and a plurality of spaced table index dogs to actuate said latter valve simultaneously to move said rock bar to an operative position and to initiate an infeeding movement of the grinding wheel.

11. In a grinding machine as claimed in claim 10, in combination with the parts and features therein specified of a fluid actuated control valve in said control valve unit which is controlled by said table-actuated valve to delay action of the rock bar motor in its movement to an inoperative position so that the wheel slide starts moving to an inoperative position before the rock bar motor is actuated to move the rock bar to an inoperative position.

12. In a grinding machine, as claimed in claim 10, in combination with the parts and features therein specified of a fluid actuated control valve in said control valve unit, operative connections between said latter valve and the table actuated valve to actuate said valve as the table approaches an indexed position to slow down the movement of the table.

13. In a grinding machine as claimed in claim 10, in combination with the parts and features therein specified of a cycle start-stop valve to control the flow of fluid under pressure to the table actuated reversing valve, an interlock valve to control the flow of fluid under pressure to the start-stop valve, and means on said rock bar to actuate said interlock valve when the rock bar is moved to an inoperative position to facilitate the flow of fluid under pressure to the table reversing valve only when the rock bar is in an inoperative position.

14. In a grinding machine having a longitudinally movable table, means including a fluid motor to move said table longitudinally in either direction, a table actuated reversing valve therefor, a transversely movable wheel slide having a rotatable grinding wheel, means including a nut and screw feed mechanism to feed said slide in either direction, a fluid motor to actuate said nut and screw mechanism, a truing apparatus mounted on said wheel slide including a fluid motor to traverse said truing tool longitudinally, a fluid actuated control valve therefor, and operative connections between the table reversing valve and said fluid actuated valve to initiate a truing operation by and in timed relation with actuation of the reversing valve.

15. In a grinding machine, as claimed in claim 14, in combination with the parts and features therein specified of means actuated by and in timed relation with the longitudinal reciprocation of the truing tool to impart a predetermined feeding movement to the truing tool at each end of the truing tool stroke, and means independently to adjust the extent of feed at each end of the longitudinal stroke of the truing tool.

16. In a grinding machine as claimed in claim 14, in combination with the parts and features therein specified of a feeding mechanism including a pawl-actuated nut and screw actuated by and in timed relation with the longitudinal movement of the truing tool to impart a predetermined feeding movement to the truing tool at each end of a truing tool stroke, and means independently to adjust the extent of feed at each end of the truing tool stroke.

17. In a grinding machine, as claimed in claim 14, in combination with the parts and features therein specified of a wheel feed compensator including a pawl and ratchet mechanism operatively connected to impart a compensating adjustment to the wheel slide feeding mechanism, and a fluid motor to actuate said compensator, said operating connections between the table reversing valve and said fluid actuated valve simultaneously to start a truing cycle and to actuate said feed compensator to impart a compensating adjustment to the wheel feeding mechanism equal to the feed of the truing tool at both ends of the truing tool stroke.

18. In a grinding machine, as claimed in claim 14, in combination with the parts and features therein specified of a wheel feed compensator including a pawl and ratchet mechanism operatively connected to impart a compensating adjustment to the nut and screw wheel feed mechanism, a fluid motor to actuate said compensator, and operative connections between the table reversing valve and said fluid actuated control valve simultaneously to start a truing cycle and to actuate said feed compensator to impart a compensating adjustment to the wheel feeding mechanism equal to the feed of the truing tool at both ends of its stroke.

19. In a grinding machine having a longitudinally movable table, a rock bar on said table, a rotatable work support including a master cam spindle having a plurality of master cams thereon which is mounted on said rock bar, a transversely movable wheel slide having a rotatable grinding wheel, means including a fluid motor to move said slide in either direction, a feed control valve therefor, means including a fluid motor intermittently to index said table longitudinally in one direction to facilitate grinding a plurality of spaced cams on a cam shaft, a table actuated reversing valve to change the direction of movement of said table rapidly to return the table to its initial position through an idle stroke, a truing apparatus mounted on said wheel slide including a longitudinally reciprocable truing tool, means including a fluid motor to traverse said truing tool longitudinally in either direction, a fluid actuated reversing valve therefor, operative connections between the table reversing valve and the fluid actuated reversing valve to facilitate starting a truing cycle when the table reversing valve is shifted to cause an idle stroke of the table to facilitate truing the grinding wheel during the idle stroke, and an interlock valve actuated by and in timed relation with the longitudinal reciprocation of the truing tool to prevent starting the next grinding cycle until the truing tool has completed a truing cycle.

20. In a cam grinding machine having a longitudinally movable table, a rock bar thereon, a rotatable work support including a master cam spindle having a plurality of master cams which is mounted on said rock bar, a follower roller associated therewith, and a driving mechanism for said spindle including a motor, a driven pulley operatively connected to rotate said spindle, a rotatable intermediate shaft supported on said table, a pulley thereon, belt driving connections between the motor and said latter pulley, a second intermediate shaft, rock bar connections between the intermediate shafts, rock arm connections between the second intermediate shaft and said spindle, belt driving connections between the intermediate shafts, and belt driving connections between the second intermediate shaft and the driven pulley to facilitate imparting a uniform rotary motion to the driven

pulley and master cam spindle during oscillation of the rock bar.

21. In a cam grinding machine having a longitudinally movable table, a rock bar thereon, a rotatable work support including a master cam spindle having a plurality of master cams which is mounted on said rock bar, a follower roller associated therewith, and driving connections for said spindle including a motor, a driven shaft on said rock bar having a driven pulley arranged in axial alignment with the master cam spindle, driving connections between said shaft and spindle, a rotatable intermediate shaft supported on said table, a pulley thereon, belt driving connections between the motor and said latter pulley, a second intermediate floating shaft, rock arm connections between said intermediate shafts, rock arm connections between said second intermediate shaft and the driven shaft, belt driving connections between the intermediate shafts, and belt driving connections between the second intermediate shaft and the driven pulley to facilitate imparting a uniform rotary motion to the driven pulley and master cam spindle during oscillation of the rock bar.

22. In a grinding machine having a longitudinally movable table, a rock bar on said table, a rotatable work support including a master cam spindle having a plurality of cams which is mounted on said rock bar, a follower roller associated therewith, means including a motor to rotate said master cam spindle, means including a counter to control said motor, means actuated during oscillation of the rock bar to stop the rotation of said motor after a predetermined grinding operation has been completed and simultaneously to move the rock bar and grinding wheel to inoperative positions, and means actuated by movement of the rock bar to start the work drive motor when the rock bar is moved to an operative position for grinding a cam.

23. In a cam grinding machine, as claimed in claim 22, in combination with the parts and features therein specified of a work stop positioning mechanism for stopping the work piece in a predetermined loading position after the last cam on the shaft has been ground including a cam on the master cam spindle, a limit switch actuated thereby when the rock bar is in an operative position, and a second limit switch connected in series with the first limit switch which is actuated by and in timed relation with the longitudinal movement of the work table to facilitate stopping the work piece in a predetermined position herewith after the last cam has been ground.

24. In a grinding machine having a longitudinally movable work table, a rock bar on said table, a rotatable work support including a master cam spindle having a plurality of master cams which is mounted on said rock bar, a follower roller associated therewith, means including a two-speed motor to rotate said master cam spindle, means to control the fast speed of said motor during an initial grinding operation, means to control the slow speed of said motor during a final grinding operation, a counter for controlling the fast speed, means actuated by movement of the rock bar to an operative position to energize said counter, means actuated during oscillation of the rock bar to impart an impulse to said counter to control the duration of the initial grinding speed, a second counter to control the slow speed control means to control the duration of the final grinding speed, said second counter serving at count-out to initiate stopping the work drive motor after a predetermined grinding operation has been completed and to move the rock bar and the grinding wheel to inoperative positions, and a limit switch actuated by movement of the rock bar to and from an operative position to start the work drive motor when the rock bar is shifted to an operative position for grinding the next cam.

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