

May 17, 1938.

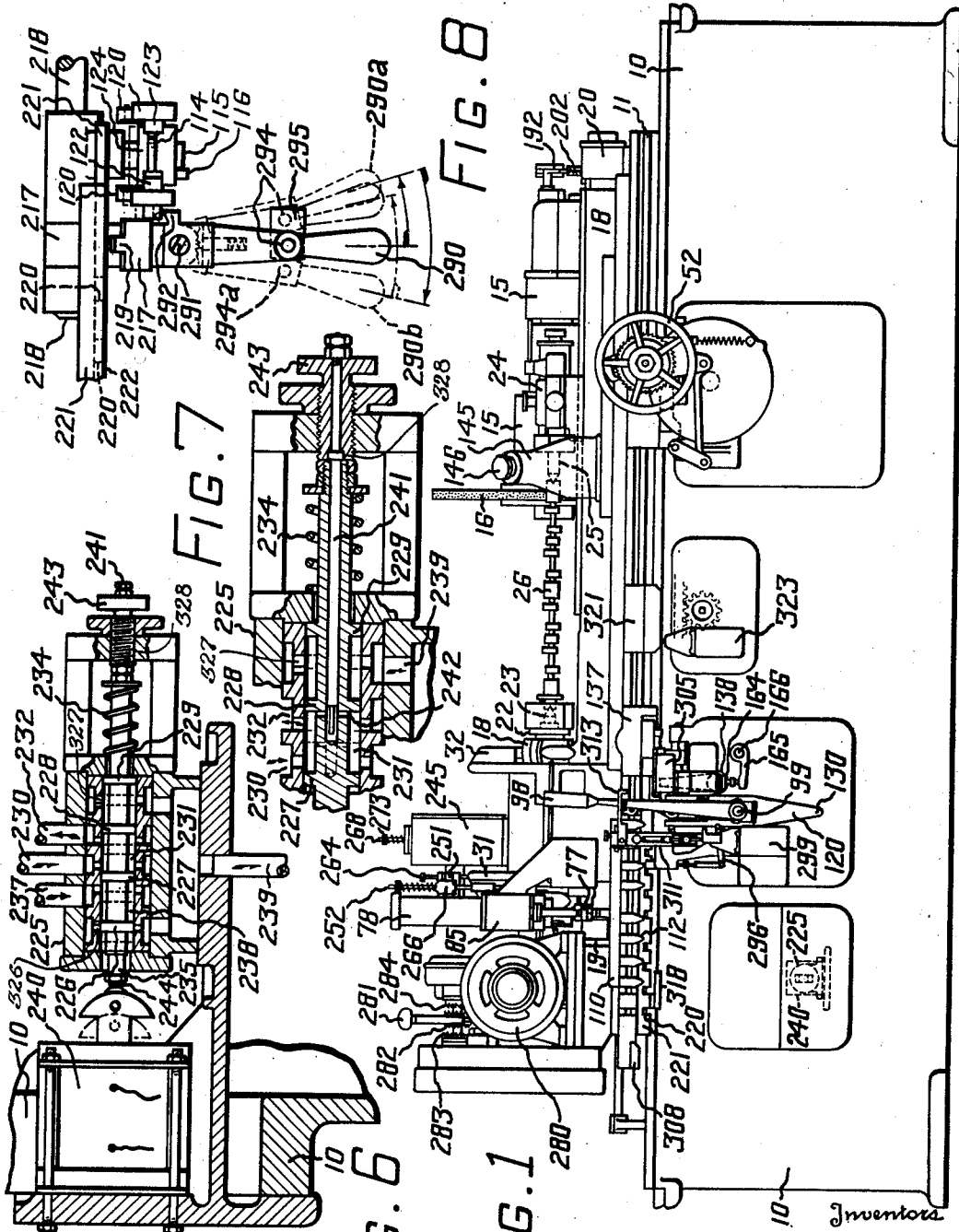
H. A. SILVEN ET AL

2,117,916

AUTOMATIC CAM GRINDING MACHINE

Filed Dec. 26, 1935

6 Sheets-Sheet 1



WITNESS

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FIG. 1

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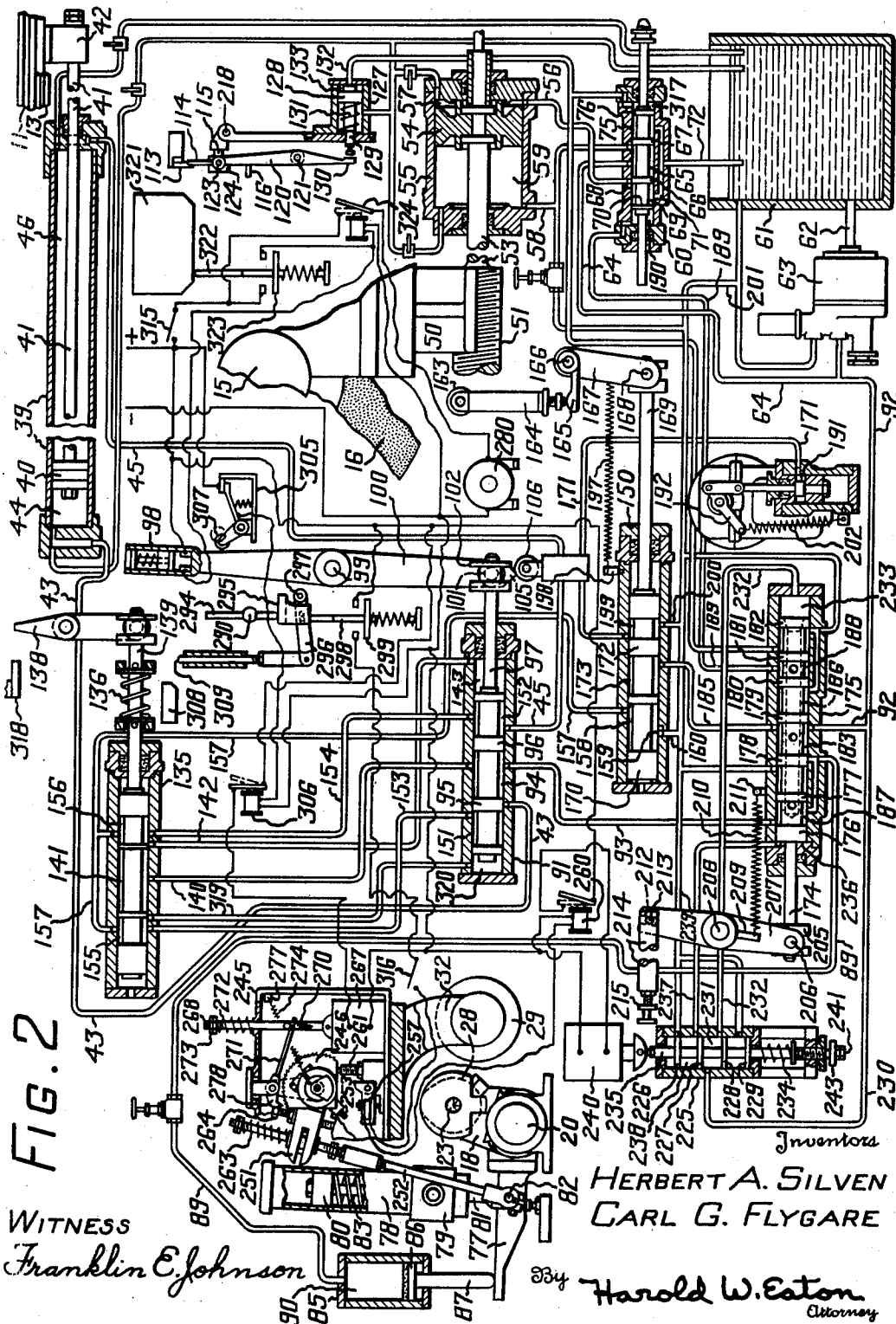
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AUTOMATIC CAM GRINDING MACHINE

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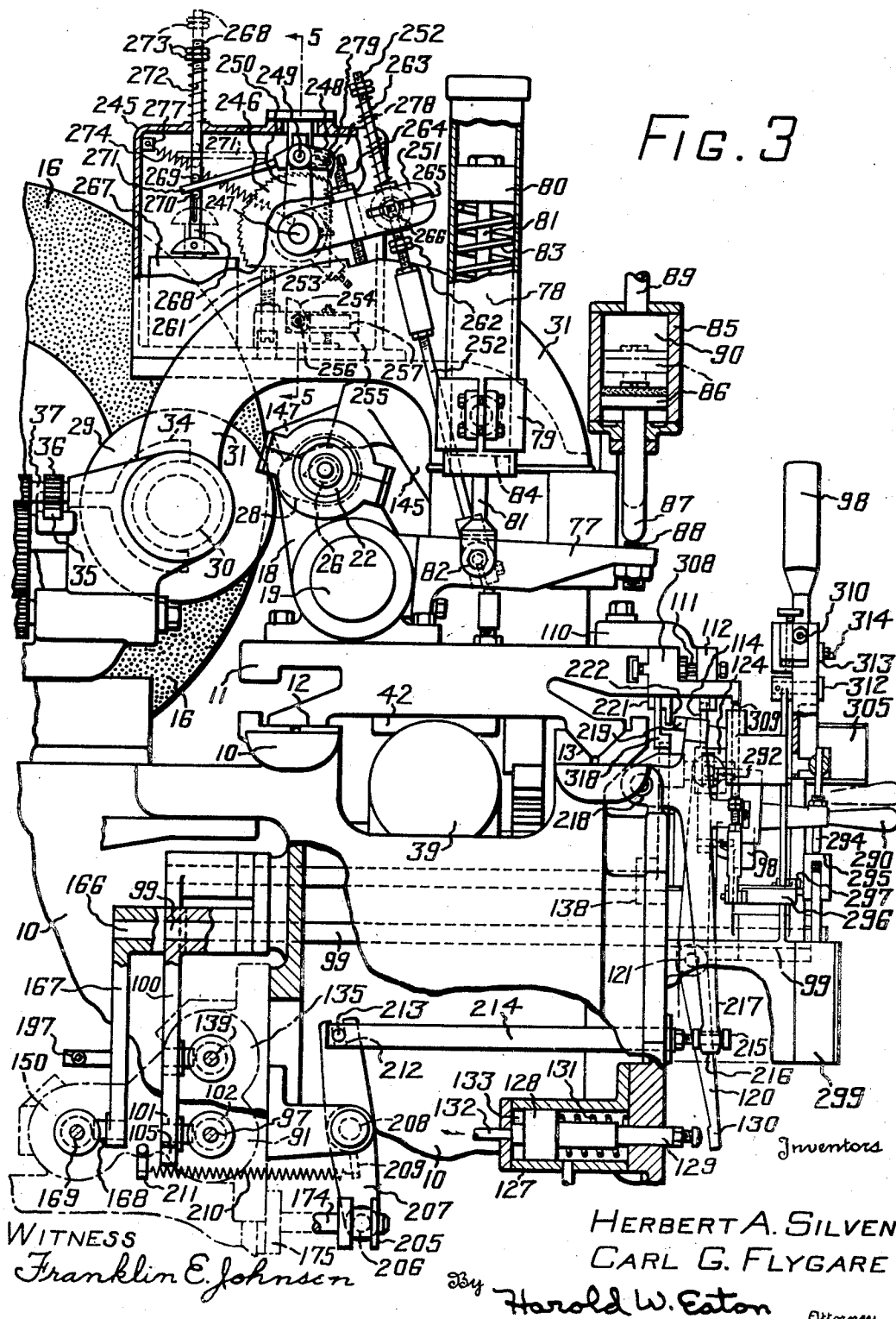
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AUTOMATIC CAM GRINDING MACHINE

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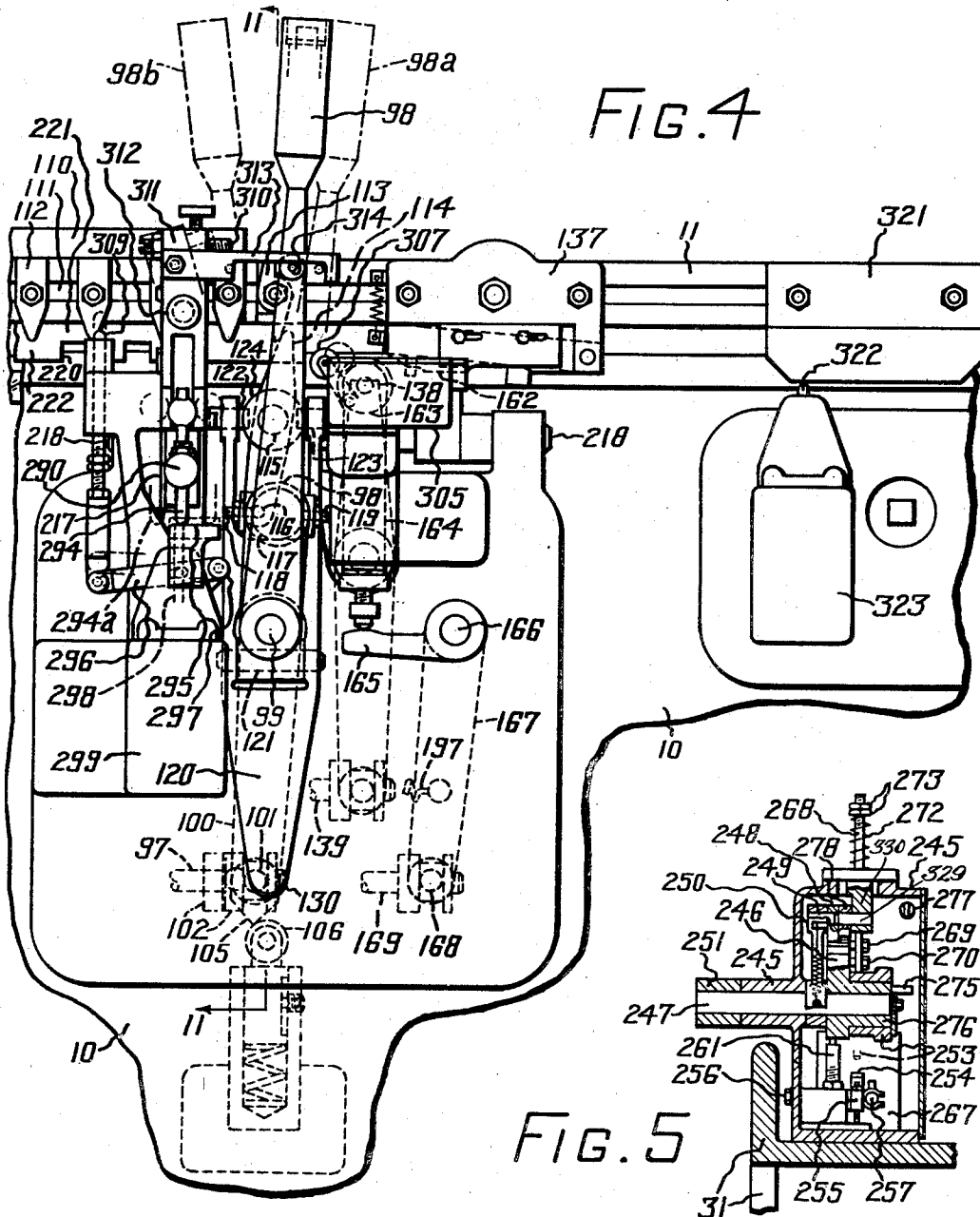


FIG. 5

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AUTOMATIC CAM GRINDING MACHINE

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6 Sheets-Sheet 5

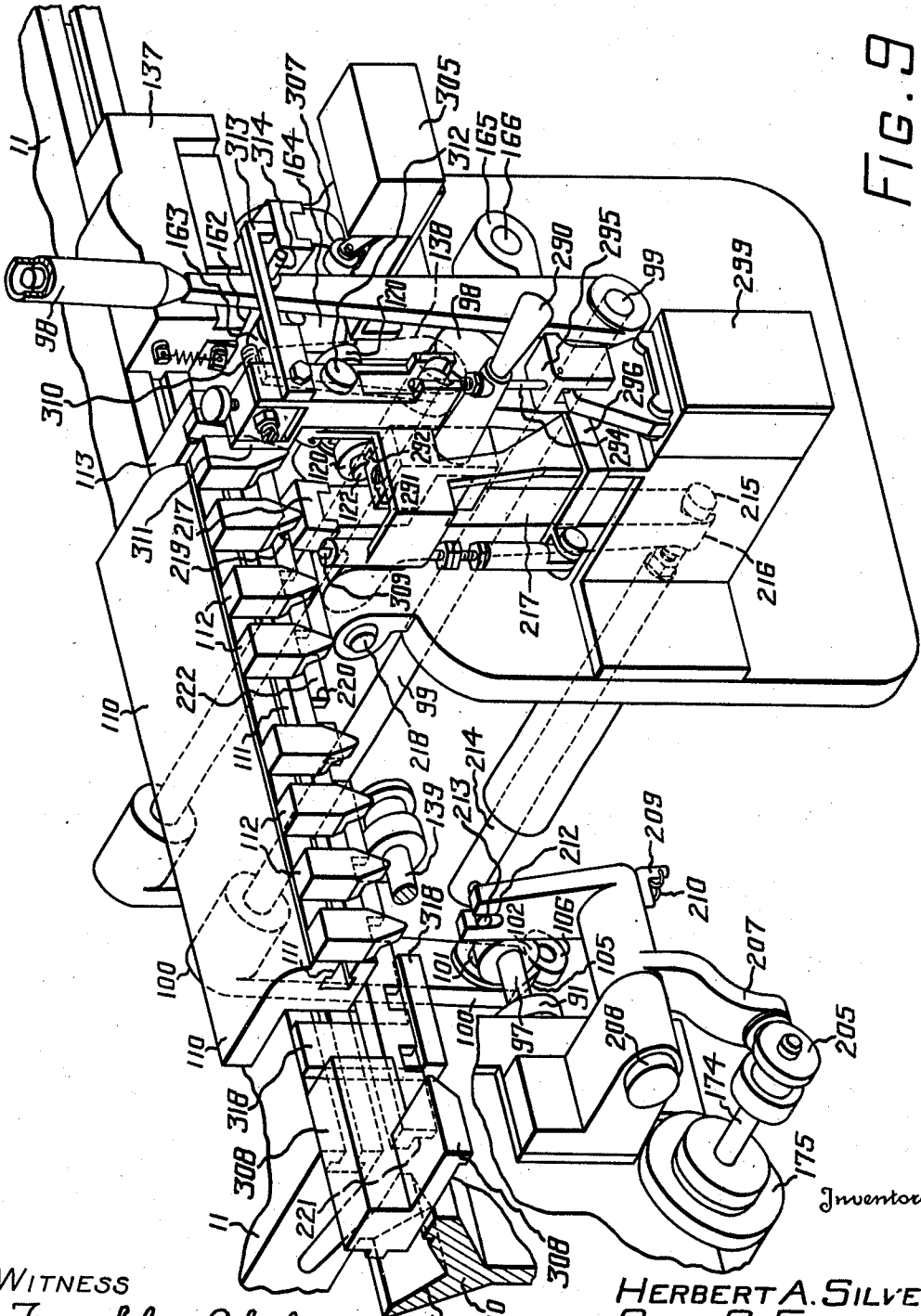


FIG. 9

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AUTOMATIC CAM GRINDING MACHINE

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6 Sheets-Sheet 6

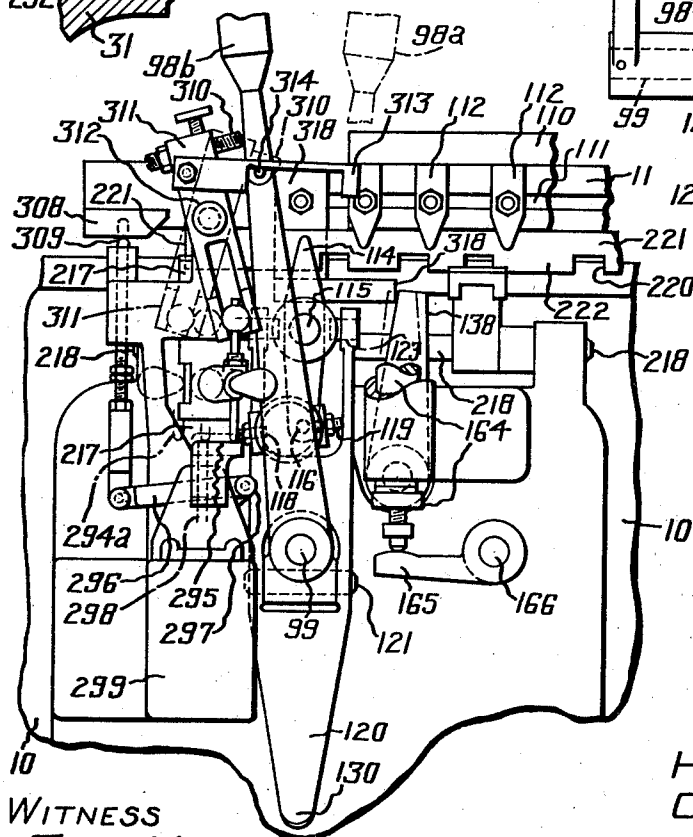
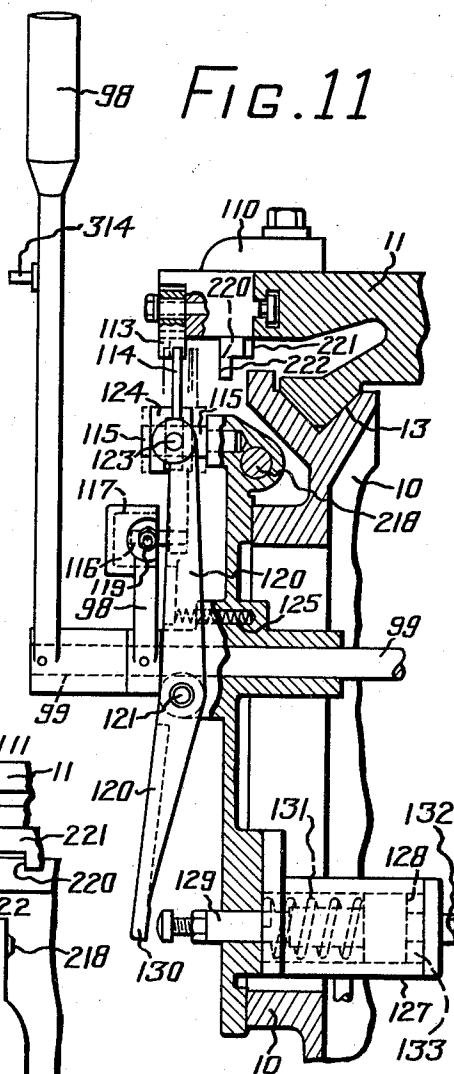
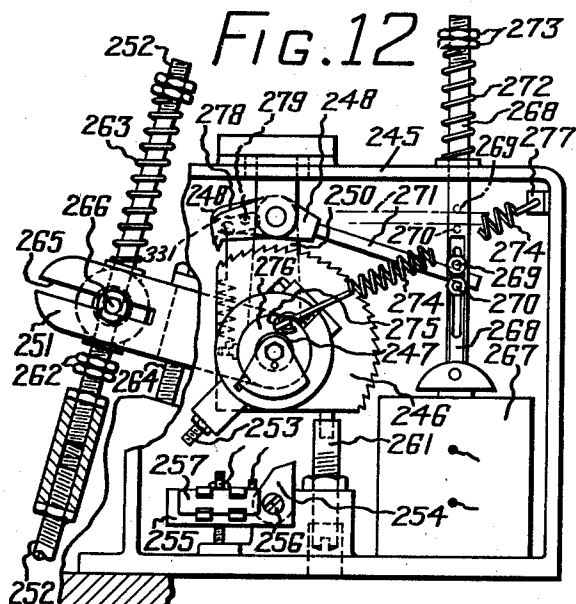


FIG. 10

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UNITED STATES PATENT OFFICE

2,117,916

AUTOMATIC CAM GRINDING MACHINE

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Application December 26, 1935, Serial No. 56,148

14 Claims. (Cl. 51-101)

This invention relates to grinding machines, and more particularly to an automatic camshaft grinding machine.

One of the objects of this invention is to provide a simple and thoroughly practical machine for automatically grinding a plurality of cam blanks on an integral camshaft. A further object of this invention is to provide an automatic cycle controlling mechanism for controlling the feeding movement of the grinding wheel, the positioning movement of the work table, and the rocking movement of the cam toward and from the grinding wheel to grind successive cams automatically to a predetermined size and contour.

Another object of this invention is to provide an automatic cycle controlling mechanism in which a cycle controlling valve is actuated after the cam being ground has rotated a predetermined number of rotations in contact with the grinding wheel. A further object is to provide an electrically controlled hydraulic mechanism for controlling a cycle control valve which in turn controls the admission of fluid to the wheel feed cylinder, the table positioning cylinder and the rock bar cylinder.

A further object of this invention is to provide a counting mechanism which operates after a predetermined number of rotations of the work to actuate a cycle pilot valve to shift a main control valve to control the cycle of operation of the machine. Other objects will be in part obvious or in part pointed out hereinafter.

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

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

Fig. 1 is a front elevation of a grinding machine embodying this invention;

Fig. 2 is a diagrammatic view showing the piping diagram and the electrical control circuit;

Fig. 3 is a fragmentary left end view of the grinding machine shown in Fig. 1, having parts broken away and shown in section to more clearly show the construction;

Fig. 4 is a fragmentary front elevation of the control mechanism shown in Fig. 3;

Fig. 5 is a vertical sectional view, taken approximately on the line 5-5 of Fig. 3, showing the details of the counting mechanism and the nose lifting device;

Fig. 6 is a fragmentary sectional view, on an enlarged scale, showing the cycle pilot valve and its actuating solenoid;

Fig. 7 is a fragmentary sectional view, on an enlarged scale, of the right end of the cycle pilot valve shown in Fig. 6;

Fig. 8 is a fragmentary view, on an enlarged scale, of the main control lever for starting the cycle of operation;

Fig. 9 is a fragmentary perspective view, on an enlarged scale, showing the details of the lever controlling mechanism;

Fig. 10 is a fragmentary view, on an enlarged scale, of the control lever mechanism when the work is at its extreme right-hand position;

Fig. 11 is a fragmentary sectional view taken approximately on the line 11-11 of Fig. 4; and

Fig. 12 is an enlarged right-hand end elevation of the cycle control mechanism with the cover removed.

A 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 base 10 also supports a transversely movable wheel slide 15 on ways (not shown) for a transverse feeding movement toward and from the work supporting table 11. The wheel slide 15 supports a rotatable grinding wheel 16.

The longitudinally movable work table 11 supports a pivotally mounted rock bar 18 which is supported in bearings 19 and 20 on the table 11 (Figs. 1 and 3) and is arranged so that it may be rocked about an axis which is substantially parallel to the axis of the grinding wheel 16. The rock bar 18 is provided with a rotatable headstock spindle 22 and a headstock center 23. The rock bar also supports a footstock 24 having a footstock center 25. The headstock center 23 and footstock center 25 are arranged to rotatably support a camshaft 26 to be ground.

Master cams and roller

In order that the cams on the camshaft 26 may be ground to a predetermined size and contour, it is desirable to provide a series of master cams for controlling the rocking movement of the rock bar 18 so as to rock the cam being ground toward and from the wheel periphery to generate a predetermined shape thereon. The headstock spindle 22 is provided with a plurality of master cams 28 which are mounted on the headstock spindle which is in axial alignment with the axis of the camshaft 26 being ground. A master cam roller or follower 29 is slidably

mounted on a rotatable shaft 30 which is rotatably supported in brackets 31 and 32 (Figs. 1 and 3). The master cam roller 29 is preferably indexed automatically as the table 11 is moved longitudinally to position the master cam roller 29 opposite the master cam 28 which corresponds to the cam being ground on the camshaft 26. A slidably mounted yoked member 34 straddles the master cam roller 29 and is connected to a slidable rack bar 35 which meshes with a gear 36. The gear 36 is rotatably supported on one end of a rotatable shaft 37 which is preferably rotated by a train of gears by means of a star wheel and dog bar (not shown) the latter of which is fixed to the base of the machine. The details of the master cam roller indexing mechanism have not been completely illustrated since this feature is not considered part of the present invention. For a detailed disclosure of the automatic shifting of the master cam roller, reference may be had to the prior United States Patent No. 1,783,755 to Trefethen and Belden and also to the United States Patent No. 2,022,178 to Belden and Silven dated November 26, 1935.

Table traverse

The work supporting table 11 is moved longitudinally relative to the base 10 by means of a fluid pressure operated mechanism comprising a cylinder 39 which is fixed to the base 10. A piston 40 is slidably mounted within the cylinder 39 and is connected by means of a piston rod 41 with a bracket 42 depending from the table 11. Fluid under pressure may be admitted either through a pipe 43 into a cylinder chamber 44 to cause the piston 40 and the table 11 to move toward the right, as viewed in Fig. 2, or it may be admitted through a pipe 45 into a cylinder chamber 46 to cause the piston 40 and the work supporting table 11 to move toward the left, as viewed in Fig. 2. The admission of fluid to the cylinder 39 is controlled by a valve mechanism to be hereinafter described.

Wheel feed

The wheel slide 15 may be moved transversely on the base 10 by a feeding mechanism which may be actuated either manually or hydraulically, as desired. In the preferred construction, the wheel slide 15 is provided with a depending nut 50 which meshes with a rotatable feed screw 51 which is preferably connected so that it may be rotated by a manually operable feed wheel 52 on the front of the machine base 10. The feed screw 51 is arranged so that it may be moved bodily in an endwise direction to rapidly move the grinding wheel slide 15 and the grinding wheel 16 either toward or away from the work. This is preferably accomplished by providing the feed screw 51 with a rearwardly extending piston rod 53 which carries a piston 54 slidably mounted within a cylinder 55.

The fluid pressure system may be supplemented by a hydraulically operated dash pot feed control (not shown). This dash pot mechanism may be arranged as shown in the patent to Silven No. 2,023,704 dated December 10, 1935. The dash pot feed control mechanism has not been illustrated in the present application, since this feature is not considered a part of the present invention. For further details of this dash pot construction, reference may be had to the above-mentioned patent. By utilizing a dash pot mechanism of this type, the wheel may be advanced rapidly by admitting fluid under pressure through a pipe 56

into a cylinder chamber 57 to move the wheel slide rapidly up to a position where the wheel is about to contact with the cam to be ground. Then the dash pot piston is picked up by the piston rod 53 and the further advance of the grinding wheel in grinding the camshaft is controlled by the exhaust of fluid from the dash pot cylinder. In order to remove the grinding wheel from contact with the work after the cam being ground has been ground to a predetermined size and contour, the admission of fluid under pressure to cylinder 55 is reversed and fluid is admitted through a pipe 58 into a cylinder chamber 59. A reversing valve 60 is provided to control the admission of fluid to the cylinder 55. In the position of the parts as shown in the diagrammatic view in Fig. 2, fluid under pressure from a tank or sump 61 within the base 10 passes through a pipe 62 and is forced under pressure by a fluid pump 63 through a pipe 64 into a valve chamber 65 between the valve pistons 66 and 67. In the position of the valve 60, as shown in Fig. 2, fluid under pressure entering the valve chamber 65 passes outwardly through the pipe 58 and into the cylinder chamber 59 to cause the piston 54 to move rearwardly or toward the right, as viewed in Fig. 2, to withdraw the grinding wheel from engagement with the work.

During the rearward movement of the piston 54, fluid exhausts from the cylinder chamber 57, through the pipe 56, through a V-port 68, into a valve chamber 69, between the valve piston 70 and the valve piston 66, and through a passage 71 and exhausts through a pipe 72 into the reservoir 61. When it is desired to cause an approaching movement of the grinding wheel 16, the valve 60 is shifted so that fluid under pressure passing through pipe 64 enters the cylinder chamber 65 and passes out through V-port 68 and pipe 56 into cylinder chamber 57 to cause the piston 54 to move toward the left, as viewed in Fig. 2, and thereby cause the grinding wheel 16 to be moved transversely toward the work piece to be ground. During the forward feeding movement of the grinding wheel, fluid is exhausted from the cylinder chamber 59, through pipe 58, and passes out through a V-port into a valve chamber 75 between the valve piston 67 and a valve piston 76, and through passage 71 and exhaust pipe 72, into the reservoir 61.

Spring actuation rock bar

In order that the master cams may be maintained in operative engagement with the master cam roller during the grinding operation on a cam, a yieldable pressure device is provided which serves to yieldably maintain the master cam in contact with the follower roller. As shown in the drawings, the rock bar 18 is provided with an arm 77. A cylinder 78 is fixed to the bracket 31 pivotally by means of a circular clamping band 79. The cylinder 78 contains a piston 80 which is connected by a piston rod 81 with a stud 82 on the arm 77. A spring 83 surrounds the piston rod 81 and is contained within the cylinder 78 between the piston 80 and a head 84 fixed in the lower end of the cylinder 78. The compression of the spring 83 is of sufficient strength to maintain the master cam 28 in operative contact with the master cam roller 29 during the grinding operation. This mechanism is substantially identical with the construction shown in the United States patent to Belden and Silven No. 2,022,178 dated November 26, 1935.

Hydraulic actuation rock bar

A fluid pressure mechanism is provided to rock the bar 18 to an inoperative position automatically before the table 11 is traversed so that the master cam and follower and product cams and grinding wheel will be separated before the traversing of the table is started. This mechanism may comprise a fluid pressure cylinder 85, having a piston 86 slidably mounted therein. The piston is connected to a piston rod 87 arranged to contact with a screw 88 of the arm 77. When fluid under pressure is admitted through a pipe 89 into a cylinder chamber 90 within the cylinder 85, the piston 86 moves downwardly and contacts the screw 88 and the arm 77 to rock the bar 18 and separate the master cam 28 from the follower roller 29. A valve in the pipe 89 may be regulated to control the downward movement of piston 86 to avoid any possible jolt with too rapid movement.

Grinding wheel drive mechanism

The grinding wheel may be driven from any suitable source of power, such as a driving motor (not shown) mounted either on the base of the machine or on the floor adjacent to the machine, as shown in the prior Patent No. 2,022,178, to which reference may be had for a disclosure of the wheel driving mechanism. This feature is not considered a part of the present invention and consequently has not been illustrated in detail.

Table traverse or indexing movement

The work table 11 is traversed or indexed longitudinally and automatically by means of a fluid pressure system above described which comprises the cylinder 39 containing a piston 40 which is connected by the connecting rod 41 with the depending bracket 42 on the table 11. The admission of fluid to either cylinder chamber 44 or 45 is controlled by a table reversing valve 91. Fluid from the pump 63 passes through a pipe 92, through a pipe 93, into a valve chamber 94 between valve pistons 95 and 96. A pipe 45 is connected between the valve 91 and the cylinder chamber 46 and a pipe 43 is connected between the valve 91 and the cylinder chamber 44. It will be readily apparent from this disclosure that when the table reversing valve 91 is in the position illustrated in Fig. 2, no fluid is admitted to either of the cylinder chambers and the table will remain stationary. The valve 91 is provided with a valve stem 97 which is operatively connected to a manually operable control lever 98 mounted on a rock shaft 99 by means of a short arm 100. The arm 100 is mounted on the rear end of the shaft 99 and has a pin 101 engaging a spool 102 on the valve stem 97. It will be readily apparent from this construction that when the lever 98 is moved in a clockwise direction, the valve stem 97 will be moved toward the left, as viewed in Fig. 2, so as to admit fluid through the pipe 43, to the cylinder chamber 44, and cause a movement of the table 11 toward the right (Figs. 1 and 2). Similarly, when the lever 98 is moved in a counterclockwise direction, the valve stem 97 will be moved toward the right (Fig. 2) so as to pass fluid through the pipe 45, into the cylinder chamber 46, to move the table 11 toward the left (Figs. 1 and 2).

The lever 98 is normally held in a broken line position 98a or 98b by means of an arrow point 105 on the lever 100 fixed on the end of shaft 99 and is engaged by a spring pressed roller 106. The lever is in the broken line position

98a, while the table is indexed intermittently in a direction toward the right. The lever 98 is in a broken line position 98b, as indicated in Figs. 4 and 10, while the table is being traversed toward the left. The valve stem 97 is normally held in a position to admit fluid through the pipe 43 or the pipe 45 to the cylinder 39. The admission of fluid through the pipe 33, to the valve 91, is controlled by a main control valve, as will be described hereinafter.

An actuating mechanism is provided for the valve so that movement of the work supporting table 11 operates to close the valve 91 so that when the table is traversed a predetermined distance to position the next cam in front of the grinding wheel, the valve is automatically closed to stop the table movement. This is preferably accomplished by means of a dog bar 110 which is adjustably mounted on the front edge of the table 11 by means of bolts in elongated slots. The dog bar 110 is provided with a T-slot 111 which serves to support and guide a plurality of adjustable dogs 112. The dogs may be adjusted along the bar 110 to conform with the spacing of the cams on the camshaft to be ground. The dog bar, if necessary, for any variation in successive camshafts, may be adjusted longitudinally of the table without upsetting the adjustment of the individual dogs. In order that the control lever 98 may move in the direction of movement of the table, it is necessary to provide a secondary actuating lever for cooperating with the table dogs. As illustrated in the drawings, a dog lever 114 is pivotally mounted on a stud 115. The lower end of the dog lever 114 is provided with a projecting pin 116 which rides in a cylindrical aperture 117 in the lever 98.

Assuming the lever 98 is positioned as shown in Fig. 4, that is in a neutral position for starting of the grinding cycle, with the dog lever 114 in contact with table stop dog 113 which is adjustably mounted on the table 11, the lever 98 is thrown either manually or automatically into a position 98a to move the valve stem 97 and admit fluid through pipe 43 into cylinder chamber 44 to start the movement of the table in a direction toward the right, as viewed in Figs. 2, 4, and 9. This movement traverses the camshaft 26 supporting table 11 to bring the first product cam into operative relation with the grinding wheel. The traversing movement continues until the dog lever 114 is engaged by the first dog 112. The dog lever 114 is rocked into the position illustrated in Fig. 4, swinging the pin 116 into engagement with an adjustable stop screw 118 or if the table is indexed to the left, with a stop screw 119, both of which are carried by the lever 98. This action swings the lever 98 from the position 98a into the full line position 98, as illustrated in Fig. 4, with the arrow point 105 depressing the spring pressed roller 106. The parts, however, are adjusted so that the arrow point does not reach the high point on the spring roller, so that the roller is at all times exerting a pressure tending to move the lever 98 either in a clockwise or counterclockwise direction. The swinging of the lever 98 from the position 98a into the full line position, as indicated in Fig. 4, moves the valve stem 97 into the position, as illustrated in Fig. 2, cutting off fluid under pressure from both of the pipes 43 and 45, thereby stopping the movement of the work carrying table 11. By adjusting the position of the dogs 112 along the dog bar 110, the stopping position of the table may

be adjusted, as desired, so that the product cams will be positioned successively in operative relation with the grinding wheel.

The dog lever 114 is slidably mounted on the stud 115 so that it may be thrown out of the path of the dogs 112 to permit a further traversing movement of the table. A lever 120 is pivoted on a stud 121 and at its upper end is formed as a yoke having pins 122 and 123 engaging slots in opposite sides of a hub 124 of the lever 114. When the lever 120 is moved from the full line position, as indicated in Figs. 2 and 11, and rocked in a clockwise direction, as shown in Fig. 11, the dog lever 114 is moved rearwardly or toward the right, as shown in Fig. 11, on the stud 115, out of the path of the dogs 112, so as to permit a further traversing or indexing movement of the table. A spring 125 maintains dog lever 114 in alignment with dogs 112 during the indexing traverse of table 11. This movement is preferably accomplished in timed relationship with the other operating mechanisms of the machine. A fluid pressure cylinder 127 is mounted within the machine base and is provided with a piston 128 having a piston rod 129 engaging an end 130 of the lever 120. A spring 131 which surrounds the piston rod 129 serves to normally retain the piston in its rearward position. Fluid under pressure is admitted through a pipe 132 into a cylinder chamber 133 in timed relationship with the other operating mechanisms of the machine, to rock the lever 120 in a clockwise direction (Fig. 11) and thereby slide the dog lever 114 into an inoperative position out of alignment with the dogs 112. This mechanism is preferably connected to a main control valve, which is hereinafter described, so as to operate automatically in timed relation with the other movements of the machine.

Pilot valve

After the work table has been indexed intermittently for grinding successive cams on a camshaft, it is then desirable to shift the traverse table index control valve 91 into a reverse position so that the arrow point 105 rides on the opposite side of the axis of the spring pressed roller 106. This is preferably accomplished by means of a pilot valve 135 which is of a balanced piston type and normally held in a neutral or inoperative position by means of a spring 136. When the table reaches its end position in its movement toward the left, a depending projection on an adjustable truing dog 137 mounted on table 11 (Figs. 4 and 9) engages the upper end of a pilot valve lever 138 and rocks it so as to move a valve stem 139 toward the right, as viewed in Figs. 2 and 4, so as to admit fluid which enters through a pipe 140 and a valve chamber 141 into a pipe 142 which passes fluid under pressure into a valve chamber 143 at one end of the table reversing valve 91. This pressure moves the valve stem 97 so that the control lever 98 and the arrow point 105 pass over the high point on the spring pressed roller 106 and shift the valve 91 into a reverse position so that after truing of the grinding wheel, the table 11 is ready for an intermittent traversing or indexing movement in a direction toward the right, as viewed in Figs. 1, 2 and 4.

Wheel truing mechanism

In a machine of this type, it is desirable that the grinding wheel be automatically trued in between operations so that a freshly trued grinding wheel face may be presented at the start of

each grinding operation. A truing apparatus comprising a bracket 145 is fixedly mounted on the table 11 and carries a truing tool 147 (Fig. 3) which may be adjusted by means of a micrometer mechanism 146. The details of the truing mechanism have not been illustrated in detail since this feature is not considered a part of the present invention. For further details as to this mechanism, reference may be had to the U. S. patent to Belden and Silven No. 2,022,178 dated November 26, 1935. After the last cam on the shaft has been ground, the grinding wheel is moved to an extreme rearward position with the piston 54 engaging the rear end of the cylinder 55 (Fig. 2). The table is then given an additional traversing movement to carry the previously adjusted diamond or truing tool across the operative face of the grinding wheel 16, while it is in its extreme rearward position.

The normal traversing or indexing movement of the table is comparatively rapid to prevent loss of time between successive grinding operations. The normal table speed is not at all suited for a truing operation which requires a very slow, uniform relative traversing movement between the truing tool and the grinding wheel. To obtain a slow traversing movement of the table, a suitable slow feed or throttle valve 150 is provided. When fluid is exhausted from the cylinder 39 through either pipe 43 or 45, it passes through either a valve chamber 151 or 152, pipes 153 or 154 respectively, and then through a valve chamber 155 or 156 in the pilot valve 135 and through a common exhaust pipe 157 which enters a valve chamber 158 in the slow speed valve 150. A V-port 159 in the valve chamber 158 is connected by a pipe 160 with the reservoir 61. During the normal traversing or indexing movement of the table, the V-port 159 is wide open, permitting unrestrained exhaust of fluid from the cylinder 39. When the table 11 indexes or traverses from the last cam on the camshaft and moves toward a truing position, a depending cam surface 162 on truing dog 137 strikes a roller 163 which is mounted on the upper end of a spring-pressed plunger 164. The lower end of the plunger engages a rock arm 165 mounted on the outer end of a rock shaft 166. The other end of the shaft 166 carries a rock arm 167 which is connected by a pin 168 to move a valve stem 169 of the slow speed valve 150. When the cam surface 162 moves the roller 163 downwardly, it rocks the shaft 166 and arm 167, and the valve stem 169 moves a valve piston 170 toward the right, as viewed in Fig. 2, to partially close the V-port 159, thereby restricting the exhaust of fluid from the table traversing cylinder 39 so as to produce a slow traversing movement of the work table and the diamond or truing tool across the operative face of the grinding wheel 16.

At the same time, the slow speed valve moves to throttle the exhaust of fluid to cause a slow truing movement of the table. A pipe 171 is uncovered by movement of a valve piston 172 to admit fluid under pressure from a pipe 185 through a valve chamber 173 to the pipe 171, into a cylinder chamber 191 to actuate a lever 192 and thereby stop the wheel spindle reciprocation during the truing movement. The table continues its truing movement toward the left, until the pilot valve lever 138 engages a depending projection on an adjustable truing dog 137 to move the pilot valve 135 from a neutral position and admit fluid under pressure into the valve chamber 143 of the table traverse valve 91 to

reverse the direction of travel of the table. The table also moves slowly to pass the diamond across the face of the wheel on its return stroke. The slow movement continues until the roller 163 rides up the cam surface 162 on the dog 137 as the table approaches the first cam on the shaft into position for starting the next grinding cycle.

A spring 197 connected between the lever 161 and a stud 198 on the valve 150 serves to return the valve stem 169 to its normal position so as to uncover the pipe 171 to allow fluid to exhaust from the cylinder chamber 191, through the pipe 171, a valve chamber 199, a pipe 200, and a pipe 201, into the reservoir 61, thus allowing the spring 202 to swing the lever 192 to start the wheel spindle reciprocation ready for the grinding of the next camshaft. At the same time, the V-port 159 is uncovered and unrestricted exhaust of fluid from the table traverse cylinder 39 starts the table 11 at its normal traversing or indexing speed.

While the apparatus shown is set to pass the diamond across the face of the wheel once in each direction, it is possible to adjust the truing dog 137 so that a cam actuated star wheel will provide a greater number of passes of the diamond across the operative face of the grinding wheel, if desired. The details of construction of the truing dog have not been illustrated in the present case, since this feature is not considered a part of the present invention. Reference may be had to the prior United States patent to Beiden and Silven No. 2,022,178 dated November 26, 1935 for details of disclosure of the truing dog.

Main control valve

In a machine of this type, the mechanisms function automatically to successively grind a plurality of cam blanks on a camshaft to a predetermined size and contour, and it is essential that all of the mechanisms be properly timed. Inasmuch as most of the mechanisms of the machine are controlled by fluid pressure mechanisms, it is desirable to provide a main control valve 175 which is so constructed as to admit fluid under pressure successively to the various mechanisms of the machine to produce the desired cycle of operation. As illustrated in the drawings, the main control valve 175 having a valve stem 174 is arranged to control the movement of the hollow valve member having valve pistons 176, 177, 178, 179, 180, 181, and 182. Fluid under pressure from the pump 63 passes through the pipe 92, into a valve chamber 183 in the main control valve 175. From this valve chamber, fluid under pressure passes through a pipe 185 to the slow speed or throttle valve 150. Fluid under pressure from the valve chamber 183 also passes through a central aperture 186 extending longitudinally within the main control valve. Fluid from the passage 186 enters a valve chamber 187 and passes out through the pipe 93 into the valve chamber 94 of the traverse or table index control valve 91. At the same time, fluid under pressure passing through the central aperture 186 passes into a valve chamber 188 and out through a pipe 189 into a valve chamber 190 in the wheel feed control valve 60. Fluid under pressure entering the valve chamber 190 serves to move the feed control valve 60 in a direction toward the right (Fig. 2) to uncover the pipe 58 so as to cause a rearward feeding movement of the grinding wheel 16.

The main control valve stem 174 is provided

with a spool shaped member 205 which is connected by a stud 206 carried by a lever 207 pivotally mounted on a rock shaft 208. The lever 207 is provided with a stud 209 which is connected to one end of a spring 210, the other end of which is fastened to a stud 211. The spring 210 tends to move the valve piston of the main control valve 175 toward the right, as viewed in Fig. 2. The upper end of the lever 207 is provided with a notch 212 within which a pin 213 rides. The pin 213 is mounted on the inner end of a link 214. The forward end of the link 214 is provided with a spool shaped member 215 which is arranged to be engaged by a yoked end 216 of a lever 217 which is pivotally mounted on a rock shaft 218. The upper end of the lever 217 is provided with a projection 219 which is arranged to drop into any one of a plurality of notches 220 in the bar 221 which are spaced so that the projection 219 is aligned with a notch on the bar 221 only when a cam to be ground is in operative position with relation to the grinding wheel. During the traversing movement of the table 11, the projection 219 of the lever 217 is prevented from dropping into the notches 220 by the surfaces 222 on the bar 221. These surfaces prevent the main control valve from being shifted to cause an infeeding movement of the grinding wheel except when the cam to be ground is opposite the grinding wheel.

Cycle pilot valve

In order that the main control valve 175 may be shifted to control the cycle of operation as desired, a cycle pilot valve 225 is provided. This valve is of the piston type having valve pistons 226, 227, 228, and 229. Fluid under pressure passing through the pipe 92 passes through a pipe 230 into pilot control valve chamber 231 and, in the position illustrated in Fig. 2, passes out through a pipe 232, into a chamber 233 at the right end of the main control valve 175 and serves to move the main control valve 175 into the position illustrated in Fig. 2. A spring 234 serves to normally hold the pilot valve stem 235 to the right, as illustrated in Fig. 6, so that fluid under pressure enters the pilot valve chamber 231 and passes through pipe 232 into chamber 233 to normally hold the main control valve in the position illustrated in Fig. 2. When the main control valve is moved into the position illustrated by fluid passing through the cycle pilot valve, fluid is exhausted from a chamber 236 at the left-hand end of the valve 175, forcing fluid out through a pipe 237 through a valve chamber 238 in the cycle pilot valve through a V-port 326 and out through a pipe 239 which returns the fluid to the reservoir 61. A similar V-port 327 is provided to control the exhaust of fluid from the pipe 232 when the cycle pilot valve 325 is in the upward position (Fig. 2). An adjustable stop 328 is provided to limit the movement of the valve toward the right (Figs. 6 and 7). By adjusting the position of the stop 328, the aperture of the V-port 327 may be varied as desired. The spring 234 serves to retard the movement of the valve toward the left (Figs. 6 and 7) so that fluid exhausting through the pipe 237 may have ample time to pass out through V-port 326 and through pipe 239 into the reservoir.

A solenoid 240 is connected to the upper end of the valve stem 235, as illustrated in Fig. 2, and serves when energized to shift the cycle pilot valve into the dotted line position, as indicated 75

in Fig. 6. In this position of the valve pistons, fluid under pressure from the pipe 230 entering the valve chamber 231 passes through pipe 237 into valve chamber 236 in the end of the main control valve 175 to move the main control valve stem 174 toward the right, as viewed in Fig. 2. This movement of the control valve serves to admit fluid under pressure to the various mechanisms of the machine. The solenoid 240 is preferably connected in a manner to be hereinafter described, to control the movement of the cycle pilot valve which in turn controls the admission of fluid to shift the main control valve 175 at a predetermined time in the grinding cycle.

When the solenoid 240 functions to pull the valve pistons of cycle pilot valve 225 into the dotted line position, Fig. 6, the spring 234 is compressed, serving to slow down the shifting of the valve pistons to allow time for fluid to exhaust from chamber 233 and the valve stem 174 of the main control valve 175 to be near its extreme right-hand position, Fig. 2, before valve piston 229 reduces the V-port exhaust through pipe 239 to cushion the movement of valve stem 174 to its extreme right-hand position.

Similarly, when the solenoid 240 is released, the released compression of the spring 234 returns the cycle pilot valve 225 to the position indicated in full lines, Figs. 2 and 6. In order to retard the return movement of cycle pilot valve 225 to obtain smooth operation of the hydraulic units, a stationary dash pot plunger 241 having a reduced portion is slidably mounted with a cylinder and is arranged to force fluid from the cylinder through ports 242 into chamber 231. This serves to slow down the return of the valve stem 235 to the full line position, Fig. 6. Exhaust of fluid through ports 242 results in a quicker movement of valve stem 174 to the left, Fig. 2, before valve piston 226 reduces the V-port exhaust through pipe 239 from chamber 236 to cushion the movement of valve stem 174 to its extreme left-hand position, Fig. 2.

The position of valve stem 235 in either direction to cut off the V-port exhaust through pipe 239 and to control the rapidity of movement of valve stem 174 in either direction is accomplished by adjustable means, namely an adjusting screw 243 which supports the plunger 241. Valve stem 235 is adjustably connected to the solenoid 240 by means of link 244 to obtain the results explained, by means of the adjusting screw 243.

It has been found that in order to obtain the maximum production in grinding of a camshaft, if each cam is ground for a predetermined number of rotations in grinding engagement with the periphery of the grinding wheel, the cam will be ground to the desired contour and size.

Cycle control

In order to obtain the maximum efficiency from the machine, it is desirable to provide a suitable cycle control device which serves, after a cam has been rotated through a predetermined number of rotations in operative grinding contact with the wheel, to actuate the main control valve and to thereby admit fluid under pressure to cylinder chamber 90 to rock the master cams and product cams away from the grinding wheel and the master cam roller respectively, and to admit fluid to the cylinder chamber 59 to move the grinding wheel rearwardly to an inoperative position and to then admit fluid under pressure to the table traverse cylinder 39 to automatically index the

table to present the next cam to be ground into operative relation with the grinding wheel. This is preferably accomplished by means of a cycle control counting device 245 which is contained within a rectangularly shaped box on the top of the bracket 31. The counting device comprises a ratchet wheel 246 which is mounted to rotate on a shaft 247. A pawl 248 is carried by a stud 249 on an arm 250 which is connected to move with a lever arm 251 so that the two arms 250 and 251 operate as a bell crank. The arm 251 is connected by an adjustable link 252, the lower end of which is connected to the stud 32 on the arm 77 which is fixed to the rock bar 18. Each time the rock bar 18 rocks in a counterclockwise direction toward the grinding wheel 16, the bell crank lever 250, 251 serves to rock the pawl 248 idly over the teeth on the ratchet wheel 246, and when the rock bar 18 is rocked by the master cams in a clockwise direction (Fig. 3) away from the wheel 16, serving to cause a downward movement of the link 252, and through the bell crank 250, 251 serves to cause the pawl 248 to turn the ratchet wheel 246 a predetermined adjustable amount each time the rock bar moves through its rocking motion. The shaft 247 also carries an adjustable striker arm 253 which is arranged in the path of a lever 254 which serves to rock a support 255 which is pivotally mounted on a stud 256. The arm 255 carries a mercury switch 257. When the ratchet wheel 246 has been rotated through a predetermined extent, the striker arm 253 engages the projection 254 and rocks the arm 255 about its supporting pivot 256 and trips the mercury switch 257. The tripping of the mercury switch serves to close a circuit and to energize the relay 260 which in turn closes a circuit to energize the solenoid 240 to shift the cycle pilot valve 225 and thereby admit fluid under pressure to shift the main control valve 175 toward the right, as viewed in Fig. 2. It will be readily apparent from the foregoing that each time the rock bar 18 is oscillated in grinding a cam, the link 252 serves through the bell crank 250, 251 to oscillate the pawl 248 to cause a movement of the ratchet 246. The ratchet wheel 246 is limited in its motion in a counterclockwise direction (Fig. 12) by an adjustable stop 261. The link 252 is provided with adjusting nuts 262 and a spring 263 by means of which the effective length of the link 252 may be adjusted to give the desired action to the pawl 248. The extent of movement of the pawl may be controlled by means of an adjusting screw 264 which contacts bracket 31, and is carried by the arm 251 so that between the adjustment of the nuts 262 and the screw 264, the extent of movement of the pawl may be adjusted as desired.

In order that the extent of movement of the pawl 248 may be readily varied to permit adjustment of the number of ratchet teeth picked up at each actuation of the pawl 248, it is desirable to provide a means for readily adjusting the length of the lever arm 251. The lever arm 251 is provided with a slot 265 and the link 252 is adjustably clamped in the desired location within the slot 265 by means of a clamping device 266. By adjusting the position of the clamping device 266 within the slot 265, the effective length of the lever arm 251 may be varied to adjust the extent of actuation of the pawl 248.

After a cam has been ground to a predetermined extent, it is desirable to provide a suitable mechanism for withdrawing the pawl 248 from the ratchet 246 to reset the mechanism for con-

trolling the grinding of the next cam blank. This is preferably accomplished by providing a solenoid 267 which is provided with an upwardly extending rod 268 having a pair of adjustably mounted pins 269 and 270 which are arranged to engage a lever 271 which is an extension of the ratchet pawl 248. A spring 272 surrounds an upper extension of the rod 268 and is interposed between the casing 245 and the nuts 273 which are screw threaded onto the upper end of the rod 268. A spring 274 is connected to a stud 275 on a rotary member or hub 276 which carries the ratchet wheel 246. The other end of the spring 274 is connected to a stud 277 in the upper corner of the control box 245. It will be readily apparent from the foregoing disclosure that when the solenoid 267 is energized, as shown in Figs. 3 and 12, the rod 268 is pulled downwardly against the tension of the spring 272 which serves to rock the lever 271 and the pawl 248 to disengage the pawl 248 from the ratchet wheel 246. When the pawl disengages the ratchet wheel 246, the released tension of the spring 274 serves to rotate the member 276 and the ratchet wheel 246 into its initial position, as illustrated in Figs. 3 and 12, so that the lower surface of the ratchet engages the adjustable stop 261 so that the mechanism is ready to control the grinding of the next cam blank.

Referring to Figs. 3, 5, and 12, a pivotally mounted safety pawl 278 holds the ratchet wheel 246 as the pawl 248 rocks toward the grinding wheel 16 to position for feeding the ratchet wheel on its return stroke. It will be noted, therefore, that the pawl 248 rocks idly or to a feeding position when the product cam 26 has the heel or concentric portion of the cam in contact with the grinding wheel 16 and as the cam 26 rotates and the nose or lift of the cam comes in contact with the wheel 16 the ratchet wheel 246 is fed, consequently upon completion of grinding of each cam the cam 26 will leave the wheel 16 when the nose is in contact with the wheel.

The safety pawl 278 is pivotally mounted on a stud 329 which is fixed to a bracket 330 depending from the casing 245 of the counting or control mechanism. When the ratchet wheel is indexed, the safety pawl 278 rides idly over the ratchet teeth and prevents the ratchet from turning in the reverse direction. The pawl 248 as above described is carried by a stud 249 which is supported on arm 250 which is formed as one arm of a bell crank lever 250—251. When the bell crank is rocked in a clockwise direction (Fig. 3), the pawl 248 rides idly over the teeth of the ratchet wheel 246. When the bell crank lever 250—251 is rocked in a clockwise direction, the pawl 248 engaging the teeth of the ratchet wheel 246 serves to index the ratchet wheel to a new position and the safety pawl serves to hold it in its advanced position. The pawl 248 is provided with a projecting pin 279 which projects within an elongated slot 331 in the pawl 278. The pin 279 serves when the arm 271 is rocked in a clockwise direction (Fig. 12) to disengage the pawls 278 and 248 from engagement with the ratchet wheel 246 so as to allow the ratchet wheel to return to its initial position, as shown in Fig. 12.

When the lever 271 rocks to disengage the pawl 248 from the ratchet wheel 246, a pin 279 carried by the pawl 248 engages the upper surface of an elongated slot in the pawl 278 and serves to lift the pawl 278 from engagement with the ratchet wheel 246 so as to allow the released tension of spring 274 to rotate the ratchet wheel

246 to its starting position. The elongated slot in pawl 278 allows free movement of pawl 248 during rocking feeding movement.

The energizing of solenoid 267 is controlled by the control lever 38 which is hereinafter described.

Work rotation

The headstock spindle 22 may be rotated by any suitable driving mechanism, such as an electric motor 280 which is connected through a suitable gear mechanism to rotate the work driving center 23 at the desired speed. In the preferred construction, a two speed work drive is provided, such as that shown in the prior patent to Belden et al. No. 2,022,078 dated November 26, 1935, to which reference may be had for details of disclosure. A manually operable lever 281 serves to move a clutch member 282 into engagement with the clutch members 283 or 284 to rotate the work driver at either a proper speed for rough grinding or for finish grinding depending on the operation for which the machine is set. Details of the gear drive between the headstock motor 280 and the center 23 have not been illustrated in detail in the present case, since they are not considered part of the present invention. For a detailed disclosure of this mechanism, reference may be had to the prior United States Patent No. 2,022,178.

Start and trip lever

A start and trip lever 290 is pivotally mounted on a stud 291 which is fixed on the lever 217. The lever 290 is arranged to swing in a substantially horizontal plane and is provided with a projecting lug 292 which is arranged to engage an extension of pin 122 on the pivotally mounted lever 120. When the lever 290 is moved toward the right (Fig. 8) into position 290a, the lug 292 engages pin 122 and rocks the lever 120 about its pivot 121. This movement serves to move the dog lever 114 toward the grinding wheel 16, as viewed in Fig. 11, out of the path of the table stop dog 113. This movement allows the lever 100 to move in a clockwise direction due to the pressure of the spring pressed roller 106 on the arrow head 105 to move the valve stem 97 toward the left, as viewed in Fig. 2, so as to admit fluid from the pipe 93 into valve chamber 94 and out through the pipe 43 into the cylinder chamber 44 to cause the piston 40 and table 11 to move toward the right, as viewed in Figs. 1 and 2. As soon as the dog lever 114 passes the table stop dog 113, the spring 125 rocks the lever 120 in a counterclockwise direction, as viewed in Fig. 11, so that the dog lever 114 lies in the path of the dogs 112. The movement of the table 11 toward the right continues until the dog lever is engaged by the first dog 112 to position the first cam to be ground in operative relation with the grinding wheel 16. This movement rocks the lever 98 and lever 100 to shift the valve stem 97 into the position illustrated in Fig. 2, so that the valve piston 95 cuts off the flow of fluid to pipe 43, thereby stopping the movement of the table 11.

After the start lever has been shifted into position 290a (Fig. 8) to shift the dog lever 114 out of the path of the table stop dog 113 and start the table traverse movement or grinding cycle, the lever 290 is shifted back so dog lever 114 will be free to contact the first table dog 112 but not closing the limit switch 299. However, when the table is stopped by the first dog 112, the lever 290 is moved the rest of the way to position 290b to

close limit switch 299 to energize solenoid 240 to operate the cycle pilot valve 225. This serves to move a pin 294 carried by the lever 290 into position 294a out of the path of the surface 295, which serves to allow a lever 296 to rock about its supporting stud 297 and allows a rod 298 of a limit switch 299 to move upwardly to close the circuit and render the mercury switch 257 effective. Closing the limit switch 299 serves to energize a relay 260 which in turn makes a circuit to energize the solenoid 240 which shifts the cycle pilot valve 225 to the dotted line position, as shown in Fig. 6, so that fluid entering the cycle pilot valve chamber 231 passes outwardly through the pipe 237 to move the main control valve 175 toward the right, as viewed in Fig. 2, to permit the exhaust of fluid from the rock bar cylinder chamber 90 to allow the rock bar to rock in a clockwise direction (Fig. 2) towards the grinding wheel 16 so that the master cam 28 engages the master cam roller 29 and admits fluid under pressure to cause the grinding wheel slide 15 to move toward the work to grind a cam blank.

The grinding wheel continues its forward feeding movement to grind the cam to the desired size and contour and the wheel then recedes, after which fluid is admitted to the wheel feed cylinder chamber 59 to cause a rearward movement of the grinding wheel 16.

A normally open limit switch 305 is arranged so that its actuating roller 307 engages the lever 98 in the position of the parts illustrated in Fig. 2 and closes the limit switch 305 to energize solenoid 267 to return ratchet wheel 246 to its initial position. When the dog lever 114 is shifted out of the path of the table stop dog 113, the lever 98 moves in a clockwise direction into position 98a (Fig. 4) which serves to shift the valve 97 to start the table traverse. At the same time, the lever 98, which engages the roller 307 of the limit switch 305, is rocked in a clockwise direction to break the circuit and thereby deenergize a relay 306 which in turn deenergizes the solenoid 267 to render the ratchet pawls 248 and 278 of the cycle control mechanism 245 operative. The ratchet pawls 248 and 278 remain in engagement with the ratchet wheel 246 during the indexing of the table 11, the lever 98 being in position 98a and the limit switch 305 being open to make the solenoid 267 inactive.

When the work table 11 reaches the extreme position to the right, a dog 308 on the table 11 engages the vertical plunger 309 and causes it to move downwardly so as to open the limit switch 299. The opening of limit switch 299 serves to break the circuit to render the mercury switch 257 inoperative which in turn deenergizes the relay 260, thereby deenergizing the solenoid 240 so that the cycle pilot valve 225 moves downwardly (Fig. 2) due to the released tension of the spring 234. This movement of the cycle pilot valve 225 serves to shift the wheel feed control valve 60 so as to admit fluid under pressure to cause a rearward movement of the grinding wheel 16 and its supporting slide 15. This is preferably accomplished by providing a dog 308 on the table 11. The dog 308 is arranged in the path of a vertical plunger 309 which is connected to a lever 296 which cooperates with rod 298. The lever 296 is pivotally supported on a stud 297 and arranged so that when the dog 308 depresses the plunger 309, the lever 296 swings in a counterclockwise direction to depress the rod 298 of the limit switch 299 which serves to open the switch, there-

by rendering the cycle control mechanism inoperative.

The dog 308 engages the plunger 309 which is depressed. The table reversing dog 318 moves the lever 98 from position 98a to 98b. In this movement the pin 294 moves from position 294a to the full line position illustrated in Fig. 10. This is accomplished by lever 98 contacting the adjustable screw 310 carried by a swinging lever 311 mounted on a stud 312. The lever 311 carries a latch 313 which rides on pin 314 carried by the lever 98. During the indexing of the table 11 after the grinding operation, the lever 311 is in the dot-dash position, Fig. 10, which position it assumes at the start of the grinding cycle. When lever 98 swings the lever 311 to the full line position indicated in Fig. 10 the lever 290 swings into the dot and dash position indicated by an arrow (Fig. 8) to allow dog lever 114 to clear the dogs 112 on the return stroke. Table stop dog 113 which projects in further, being of the pivot type allowing swinging in one direction counterclockwise (Fig. 4), will let dog lever 114 pass by, and upon completion of the truing operation will stop the table 11 for the next grinding cycle. In the last truing pass the lever 98 is in position 98a, though pin 314 contacts latch 313 to swing lever 311 to the full line position (Fig. 4) so that dog lever 114 will move by means of spring 125 into further contacting relationship with the table stop dog 113 at the end of the grinding cycle.

Operation

Assuming the table 11 to be in its extreme left-hand or loading position, the machine is started into operation by first pushing an electric control button (not shown) to start the rotation of the grinding wheel 16, then pushing a second button (not shown) to start the rotation of the fluid pressure pump 63. Push button 315 is closed to start the rotation of the work driving motor 280. The work piece, such as a camshaft 26, is then loaded in the machine and supported between the headstock center 23 and footstock center 25. The work drive clutch is then engaged by shifting the lever 281 to engage the movable clutch member 282 with either the clutch member 283 or 284, depending upon whether a finish grinding or a rough grinding speed of the work is desired. The cycle control push button 316 is then closed to render the mercury switch 257 operative so that the machine is then under the control of the cycle counting mechanism 245. The hand lever 290 is then moved toward the right into position 290a (Fig. 8). This movement serves to rock the lever 290 about its vertical supporting stud 291 so that the lug 292 engaging the pin 122 rocks the lever 120 about its pivot 121, as viewed in Fig. 11, to move the dog lever 114 out of the path of the table stop dog 113. This movement allows the released tension of the spring pressed roller 106 to rock the levers 98 and 100 in a clockwise direction, as viewed in Figs. 2 and 4, which serves to shift the valve stem 97 toward the left, as viewed in Fig. 2, so that fluid under pressure passing through the pipe 93 into the valve chamber 94 passes outwardly through the pipe 43 into the cylinder chamber 44 to move the piston 40 and table 11 toward the right to bring the first cam on the camshaft 26 into operative grinding relation with the wheel 16. The longitudinal movement of the table continues until the first dog 112 engages the dog lever 114 which serves to rock the lever 98 from the position 98a into

position 98, thereby moving the valve stem 97 toward the right, as viewed in Fig. 2, to cut off fluid from the pipe 43 and thereby stop the movement of the table 11. When the lever 98 returns to the position illustrated in Fig. 2, the limit switch 305 closes, serving to energize a relay 306 which in turn energizes the solenoid 267 to withdraw the pawls 248 and 278 from engagement with the ratchet wheel 246 so as to allow the released tension of the spring 274 to return the ratchet wheel 246 and mercury switch 257 to a starting position ready for the control of the next grinding cycle. When lever 290 is shifted to position 290b at the start of the grinding cycle, the limit switch 299 is closed and the solenoid 240 is energized to shift the cycle pilot valve 225 to the dotted line position, as viewed in Fig. 6, so as to admit fluid under pressure from the pipe 230 through the valve chamber 231 and through a pipe 237 into the chamber 236 to move the main control valve 175 toward the right, as viewed in Fig. 2. The operator allows the table 11 to traverse to the first dog 112 before shifting the lever 290 completely over to close the limit switch 299. This movement of the main control valve 175 serves to cut off the flow of fluid through the pipe 93 to the table reversing valve 91 and serves to admit the flow of fluid under pressure through the pipe 132 into a cylinder chamber 133 to move the piston 128 toward the left, as viewed in Figs. 2 and 11, which serves to rock the lever 120 in a clockwise direction and thereby serves to move the dog lever 114 out of the path of the table dog 12. At the same time fluid under pressure passing through the pipe 132 enters a valve chamber 317 to move the wheel slide control valve toward the left, as viewed in Fig. 2, so that fluid under pressure passing through the pipe 64 enters a valve chamber 65 and passes outwardly through a pipe 56 into a chamber 57 to cause the grinding wheel to be fed into the cam being ground. At the same time the main control valve is shifted, as above mentioned, fluid is allowed to exhaust from the cylinder chamber 90 to allow the rock bar 18 to rock so that the master cam 28 engages the master cam roller 29. Rotation of the master cam roller in contact with the master cam serves to rock the camshaft to grind a cam blank to a predetermined contour. Each time the rock bar 18 rocks toward and from the grinding wheel, the cycle control counting device 245 is operated, and the link 252 and bell crank 250—251 serve to rock the pawl 248 to turn the ratchet wheel 246 until the striker 253 engages the lever 254 of the mercury switch supporting member 255 to rock the mercury switch 257 and thereby break the circuit, which serves to deenergize the relay 260 to break the circuit and deenergize the solenoid 240 which in turn releases the tension of the spring 234 to permit the cycle pilot valve 225 to move into the full line position, as illustrated in Figs. 2 and 6. This movement of the cycle pilot valve 225 allows fluid passing through the pipe 230 to enter the valve chamber 231 and to pass through the pipe 232 into a valve chamber 233 at the right-hand end of the main control valve 175 to move the valve toward the left, into the position of parts illustrated in Fig. 2. This movement of the main control valve 175 again opens the passage of fluid through the pipe 93 to valve chamber 94 and allows it to pass out through the pipe 43 to the cylinder chamber 44 to again index the piston 40 and the table 11 longitudinally to present the next cam into operative relation with the grind-

ing wheel 16. This cycle of operation is continued until each one of the successive cams on the product camshaft is ground to the desired size and contour. Each time the table 11 is indexed longitudinally to present a new product cam to the grinding wheel, the master cam roller 29 is indexed longitudinally by an indexing mechanism, not shown in the present application. This feature is not considered part of the present invention and consequently has not been illustrated in detail. For reference to the details of the master cam roller indexing mechanism, reference may be had to the above-mentioned patent to Belden and Silven No. 2,022,178 dated November 26, 1935. When the dog lever 114 is moved out of the path of the dog 112, the released tension of the spring-pressed roller 106 serves to rock the levers 98 and 100 in a clockwise direction into the position 98a.

This movement serves to open the limit switch 305 which in turn serves to deenergize the solenoid 267 and allows the pawls 248 and 278 to engage the ratchet wheel 246 so that upon oscillation of the rock bar 18 the pawl 248 may be oscillated to turn the ratchet wheel 246 after each actuation of the rock bar to control the cycle of grinding on the cam 26. After the cam has rotated through a predetermined number of rotations in contact with the grinding wheel during the grinding operation, the mercury switch 257 is tipped to break the circuit and the breaking of the circuit serves to release the relay 260 to deenergize the solenoid 240 and the released tension of the spring 234 then returns the valve 225 into the position illustrated in Fig. 2. In this position of the valve 225 fluid under pressure from pipe 230 passes through valve chamber 231 and pipe 232 into the chamber 233 at the right-hand end (Fig. 2) of the main control valve 175. This movement of the main control valve 175 serves to allow fluid under pressure to pass through the pipe 93 into the valve chamber 94 and the valve stem 97 having been previously moved toward the left when the dog lever 114 was withdrawn from the table dog 112 so that fluid under pressure entering the valve chamber 94 passes out through pipe 43 to index the piston 40 and table 11 toward the right. This movement continues until the next dog 112 engages the dog lever 114 to again stop the table movement when the next cam is in operative relation with the grinding wheel.

This cycle of events continues until the last cam on the left-hand end of the camshaft to be ground (Fig. 1) has been ground, after which the table 11 is traversed to a further position toward the right so that the wheel is to the left of the last cam on the shaft. During this movement beyond the last cam on the shaft, the dog 308 engages the plunger 309 which serves to rock the lever 296 and allows pin 294 to move freely over surface 295 and the levers 98 and 290 to take position 98b and 290a. The pin 294 holds the limit switch 299 open. This opening of limit switch 299 serves to deenergize the mercury switch 257 and allow the pawl to drop into operative contact with the ratchet wheel. At the same time, the table reversing dog 318 engages the table pilot valve lever 138 and rocks it in a clockwise direction (Fig. 10), serving to move the valve 135 toward the left, as viewed in Fig. 2. This movement serves to allow fluid under pressure passing through pipe 140 into the table pilot valve chamber 141 to pass outwardly therefrom through a pipe 319 into a valve chamber 320 in the left-hand end of the table reverse valve 91. Fluid under pressure en-

tering the reverse valve chamber 320 shifts the valve toward the right, as viewed in Fig. 2, so that the arrow point 105 passes over the high point of the spring-pressed roller 106 and the arrow point 5 serves to hold the reverse valve in a reverse position so that fluid under pressure passing through the pipe 93 into the valve chamber 94 then passes out through a pipe 45 into the cylinder chamber 46 of the table operating cylinder 10 39 to cause the table to move rapidly through an idle stroke toward the left, as viewed in Figs. 1 and 2, with lever 98 in position 98b, as viewed in Fig. 10. This movement serves to return the table to its initial or starting position. When the table 15 11 approaches the left-hand end of its movement, a truing dog 137 engages the roller 163 and depresses the same, which serves to shift the truing speed valve 150 toward the right, as viewed in Fig. 2, so that fluid under pressure exhausting from the table cylinder 39 passes through a V-port 159 to throttle the exhaust thereof and to regulate the speed of movement of the table while the truing tool 147 of the truing apparatus 145 passes across the operative face of the wheel 16. 25 The table 11 continues its traverse toward the left until the truing tool 147 passes across the face of the wheel, whereupon a depending projection of the truing dog 137 engages the lever 138 to rock it in a counterclockwise direction to move the valve stem 139 toward the right, as viewed in Fig. 2, serving to admit fluid under pressure entering through pipe 140 and valve chamber 141 out through a pipe 142 into a valve chamber 143 at the right-hand end of the table reversing 35 valve 91. This movement serves to shift the table reversing valve into the position illustrated in Fig. 2, so that the valve is in position ready to start the next grinding cycle after the finish ground camshaft has been removed and replaced with a new camshaft to be ground. When the reverse valve shifts into the position above described, the table starts its return stroke toward the right to pass the diamond across the face of the wheel a second time and continues this motion until the dog lever 114 engages the table stop 45 dog 113 which stops the table 11 just before the first cam moves into operative relation with the grinding wheel. The machine is then in a stopped position and the ground camshaft 26 may be readily removed and replaced with a fresh camshaft to be ground. 50

When the grinding wheel 16 is to be trued, it is customary to advance the wheel slide 15 so that a sufficient amount may be trued to present a 55 new grinding face to obtain best results. This may be accomplished by an adjustably mounted dog on the table 11 which actuates a mechanical feed mechanism connected to feed wheel 52. The details of this mechanism have not been completely illustrated and described inasmuch as 60 this is not part of the present invention. Reference may be had to the above-mentioned Belden and Silven Patent No. 2,022,178 for details of disclosure.

During the truing operation the headstock motor 280 is stopped by means of the adjustably 65 mounted table dog 321 to permit the removal of the finish ground camshaft 26 from the machine during the truing operation. Dog 321 slides over and depresses a rod 322 of a limit switch 323 which breaks the circuit to deenergize a relay 324 70 which stops the headstock motor 280. As the table 11 reciprocates during the truing operation the table dog 321 slides over the rod 322 and upon 75 completion of the truing operation, the table

moves to the table stop dog 113 at the end of the grinding cycle, dog 321 still maintaining contact with the rod 322. Upon starting of the grinding cycle, the dog 321 will come out of contact with the rod 322 to close the limit switch 323 5 to start the headstock motor 280 before the first cam 26 comes into operative relationship with the grinding wheel 16.

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 10 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. 15

We claim:— 20

1. A grinding machine comprising a rotatable grinding wheel, a transversely movable slide to support said wheel, a longitudinally movable table, means including a rotatable work supporting spindle on said table, means including a fluid pressure piston and cylinder to move said slide transversely, means including a fluid pressure piston and cylinder to move said table longitudinally, a control valve arranged to admit fluid under pressure to either of said cylinders, and a cycle control mechanism actuated by and in timed relation with the rotation of the work supporting spindle to actuate said control valve. 25

2. An automatic cam grinding machine comprising a rotatable grinding wheel, a transversely movable slide to support said wheel, a longitudinally movable table, a rotatable cam shaft support pivotally mounted on said table, means to move said table longitudinally, means to move said wheel slide transversely to grind successive cams to a predetermined size, means including a plurality of master cams and a follower to rock said camshaft support relative to said table and grinding wheel to cause a secondary relative transverse movement between the wheel and camshaft support to grind successive cams to a predetermined contour, a cycle control mechanism actuated by and in timed relation with the rocking camshaft support, and means actuated by said cycle control mechanism to automatically separate the grinding wheel and camshaft after the cam has rocked a predetermined number of times toward the wheel axis and to automatically index said table and camshaft longitudinally to position successive cams into operative relation with the grinding wheel. 30 35 40 45 50 55

3. An automatic cam grinding machine comprising a rotatable grinding wheel, a transversely movable slide to support said wheel, a longitudinally movable table, a pivotally mounted work support on said table, means including a rotatable camshaft supporting spindle thereon, a plurality of master cams rotatably supported on said work support in axial alignment with the camshaft to be ground and integrally attached thereto, a follower roller arranged to be operatively positioned relative to said master cams and cooperating therewith to rock said work support to produce a predetermined contour on the 60 65 cams being ground, a cycle control mechanism actuated by and in timed relation with the rotation of said master cams, and means actuated by said cycle control mechanism to control the movement of said grinding wheel toward and from the work, the rocking of said work support 70 75

and the indexing of said table to present successive cams into operative relation with the grinding wheel, and to return said work table to the initial loading position.

4. An automatic cam grinding machine comprising a rotatable grinding wheel and a work support for rotatably supporting a camshaft which are movable longitudinally and transversely relative to each other, means to cause a transverse feeding movement of the grinding wheel to grind a cam blank to a predetermined size, means to cause a predetermined transverse movement of the work support toward and from the grinding wheel to generate a predetermined contour on the cam blanks, means to cause an intermittent relative longitudinal indexing movement between the grinding wheel and the work support in one direction to position successive cams in operative relation with the grinding wheel for grinding, means to cause a rapid relative longitudinal traversing movement between the wheel and work in the opposite direction to return the wheel and work to the initial position, a truing tool carried by the work support, and means to cause a further slow relative longitudinal traversing movement between the wheel and work support to pass the truing tool automatically across the wheel face and then stop in a loading position.

5. A hydraulically driven cam grinding machine having a hydraulically moved wheel supporting member, a hydraulically traversed work supporting table, a hydraulically controlled, pivotally mounted camshaft support on said table, means including a cycle control valve to admit fluid under pressure to feed the wheel toward and from the camshaft to be ground, means to admit fluid to cause said table to be intermittently traversed longitudinally relative to the grinding wheel to position successive cams in operative relation with the grinding wheel, to admit fluid under pressure to a cylinder to cause said pivotally mounted camshaft support to be moved to an inoperative position during the indexing of the table, a control device operated in timed relation with the movement of said camshaft support, and electrically controlled means operated by said control device to actuate said main control valve after a cam has been rotated a predetermined number of rotations in operative engagement with the grinding wheel.

6. In a cam grinding machine having a pivotally mounted camshaft support and master cams and a follower to control the rocking movement of said support, a control device including an electric switch, means including a pawl and ratchet mechanism to actuate said switch, means actuated by the rocking movement of said camshaft support to intermittently index said ratchet wheel to actuate said switch, and an electrically controlled mechanism operated when said switch is actuated to cause a separation of the master cam follower when the high point of the cam being ground is in engagement with the wheel.

7. An automatic cam grinding machine comprising a rotatable grinding wheel and a rotatable work support which are movable longitudinally and transversely relative to each other to grind the surface cams on an integral camshaft, means including a fluid pressure piston and cylinder to cause a relative longitudinal indexing movement between the grinding wheel and the camshaft support to bring successive cams into operative relation with the grinding wheel, means including a fluid pressure piston and cylinder to cause a

relative transverse movement between the grinding wheel and camshaft support to grind successive cams to a predetermined size, means including a set of master cams and a follower to cause a relative transverse movement between the grinding wheel and work to grind successive cams to a predetermined contour, means including a fluid pressure piston and cylinder operatively connected to render said master cams inoperative, means including a main control valve to control the admission of fluid under pressure to each of said cylinders, and a control device including an electric switch, means including a pawl and ratchet mechanism to actuate said switch, means actuated by the relative transverse movement of said camshaft support to rotate said ratchet wheel so as to intermittently index said ratchet wheel to cause a rotary motion to be transmitted to said switch, and an electrically controlled mechanism arranged to actuate said main control valve when said switch is actuated to admit fluid under pressure to the camshaft support cylinder to separate the master cam from the follower, to admit fluid under pressure to cause a transverse separating movement between the grinding wheel and camshaft support, and to admit fluid to said first cylinder to cause a longitudinal indexing movement between the grinding wheel and the camshaft support.

8. A cam grinding machine having a wheel slide, a work table and a rock bar thereon, each of which is operated by a separate fluid motor, a main control valve in control of said motors, a pilot valve in control of said main control valve, and a cycle control mechanism actuated in timed relation with the rocking of said bar to actuate said pilot valve.

9. A cam grinding machine having a wheel slide, a work table and a rock bar thereon, each of which is operated by a separate fluid motor, a main control valve in control of said motors, a pilot valve in control of said main control valve, and a cycle control mechanism including a pawl and ratchet actuated in timed relation with the rocking of said bar during grinding to actuate the pilot valve.

10. A cam grinding machine having a wheel slide, a work table and a rock bar thereon, each of which is operated by a separate fluid motor, a main control valve in control of said motors, a pilot valve to actuate said main control valve, an electric solenoid to shift said pilot valve, and a control mechanism including an electric switch actuated in timed relation with the rocking movement of said bar during grinding to energize said solenoid.

11. A cam grinding machine having a wheel slide, a work table and a rock bar thereon, each of which is operated by a separate fluid motor, a main control valve in control of all of said motors, a pilot valve to actuate said main control valve, a solenoid to actuate said pilot valve, a control mechanism including a pawl and ratchet actuated by movement of said rock bar, and an electric switch operated thereby to energize said solenoid after a predetermined grinding operation.

12. A cam grinding machine having a wheel slide, a work table and a rock bar thereon, each of which is operated by a separate fluid motor, a wheel spindle reciprocating mechanism, a fluid motor in control thereof, a main control valve in control of all of said fluid motors, a pilot valve to actuate the main control valve, electrical means to actuate said pilot valve in timed rela-

tion with the rocking movement of said bar during the grinding operation.

13. A cam grinding machine having a wheel slide, a work table and a rock bar thereon, each of which is operated by a separate fluid motor, a main control valve in control of all of said motors, a pilot valve to actuate said main control valve, a solenoid to actuate said pilot valve and a cycle control mechanism including a pawl and ratchet actuated by and in timed relation with the rocking movement of said bar during grinding to control an electric switch so as to energize said solenoid and thereby control the grinding cycle.

14. In a cam grinding machine having a pivotally mounted camshaft support and master cams and a follower to control the rocking movement

of the support, a longitudinally movable work table, a transversely movable rotatable grinding wheel and slide, said rock bar, work table and wheel slide each being operated by a separate fluid motor, a main control valve to control all of said motors, a pilot valve to control said main control valve, a cycle control device including a pawl and ratchet actuated electric switch, connections between said rock bar and pawl to actuate the same in timed relation with the rocking of said bar, and electrically controlled mechanism operated by said switch to actuate said pilot valve and thereby control the cycle of operation.

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