

June 14, 1955

C. J. GREEN

2,710,495

CAM GRINDING MACHINE

Filed Feb. 19, 1953

6 Sheets-Sheet 1

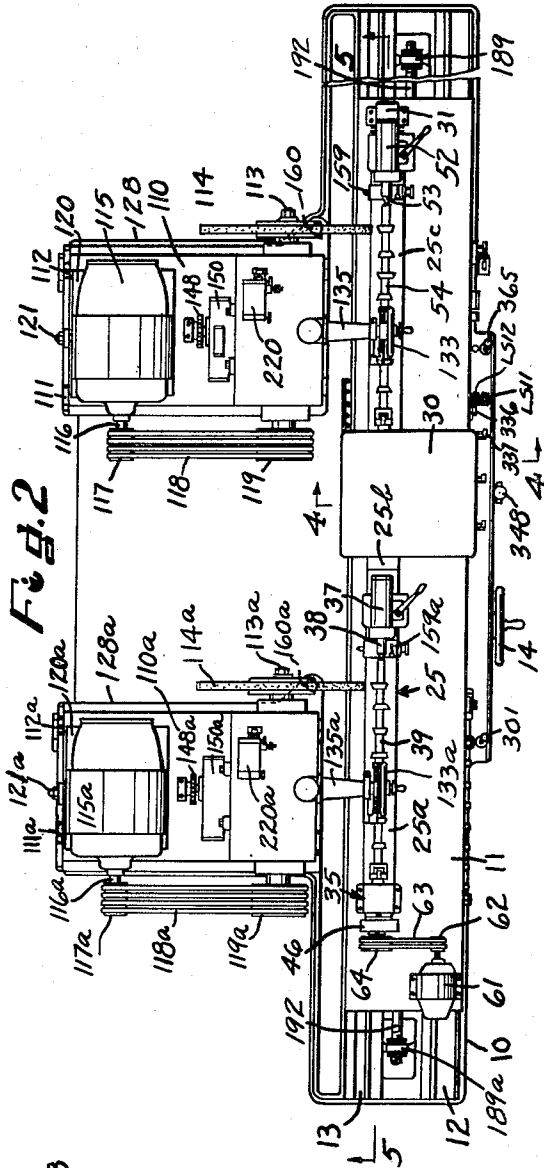


Fig. 2

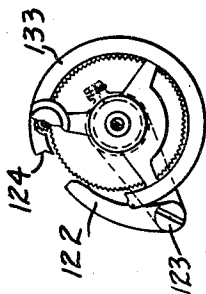


Fig. 11

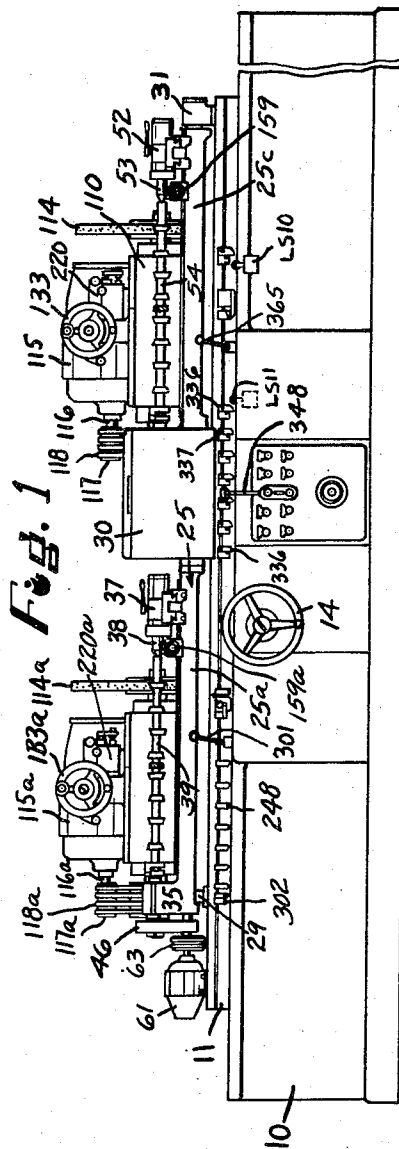


Fig. 1

INVENTOR.
CLARENCE J. GREEN
BY
Harold W. Eaton
ATTORNEY

June 14, 1955

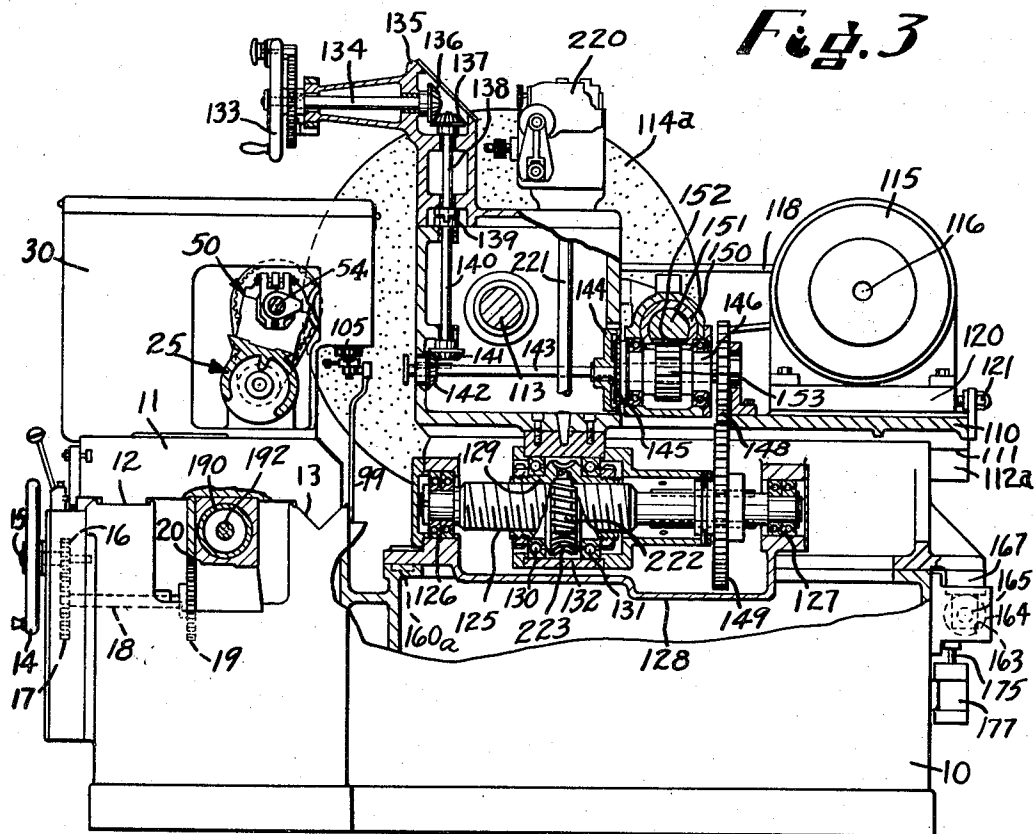
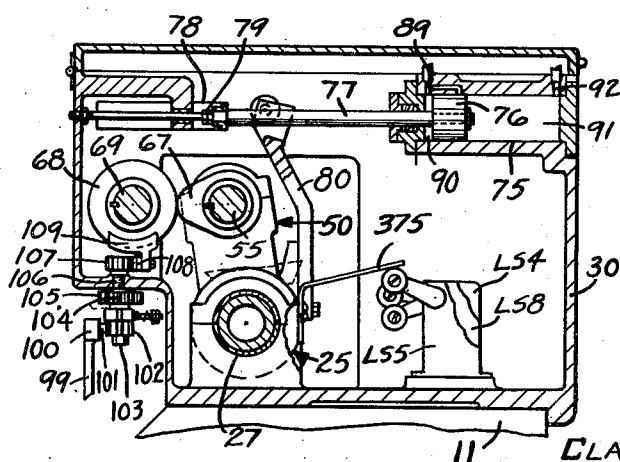
C. J. GREEN

2,710,495

CAM GRINDING MACHINE

Filed Feb. 19, 1953

6 Sheets-Sheet 2



INVENTOR.
CLARENCE J. GREEN
BY
Harold W. Eaton
ATTORNEY

June 14, 1955

C. J. GREEN

2,710,495

CAM GRINDING MACHINE

Filed Feb. 19, 1953

6 Sheets-Sheet 3

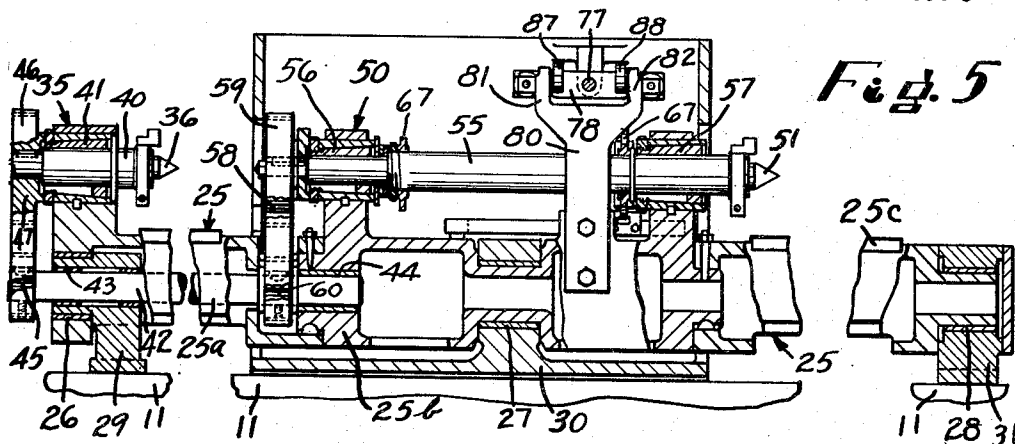
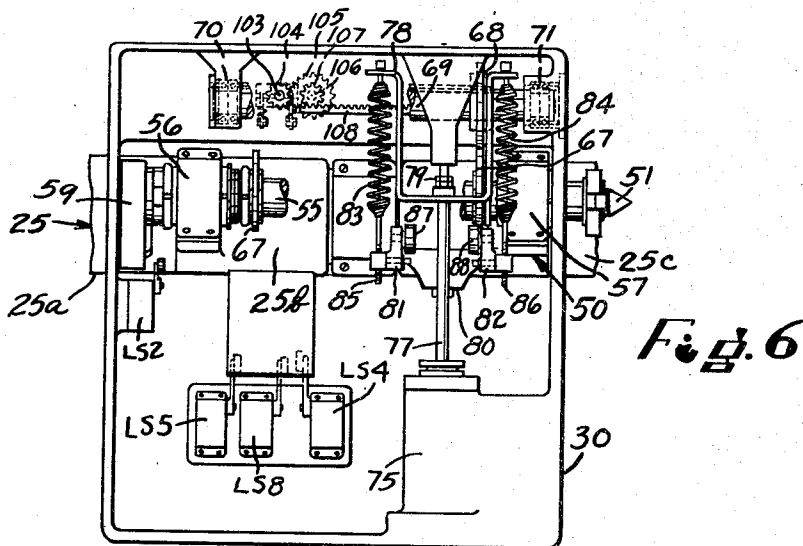
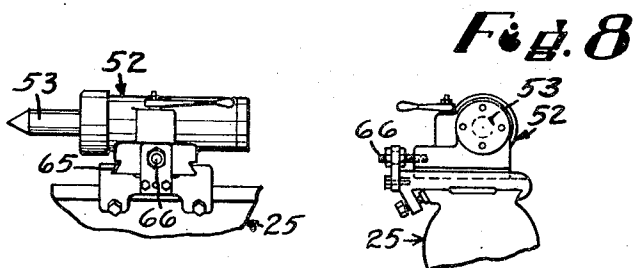


Fig. 7

INVENTOR.
CLARENCE J. GREEN
BY

Harold W. Eaton
ATTORNEY

June 14, 1955

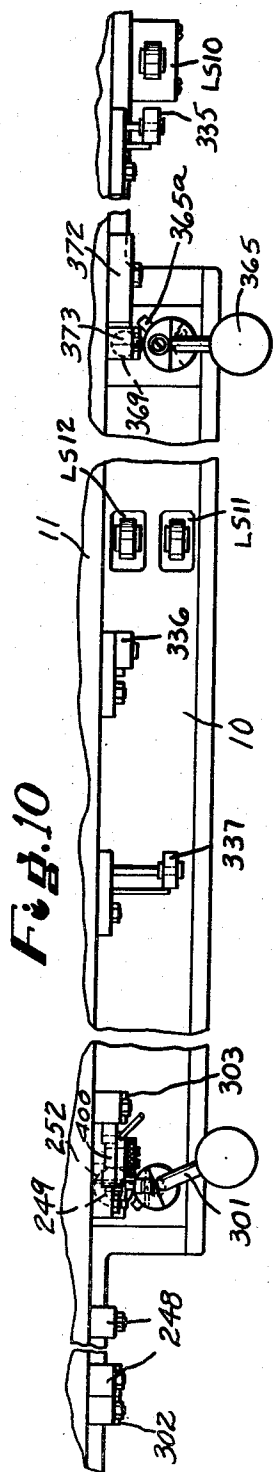
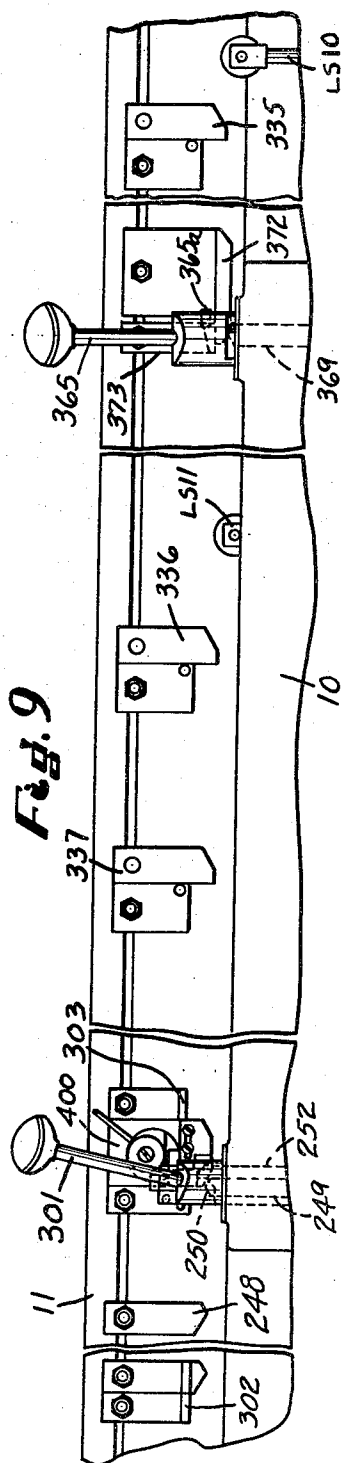
C. J. GREEN

2,710,495

CAM GRINDING MACHINE

Filed Feb. 19, 1953

6 Sheets-Sheet 4



INVENTOR.
CLARENCE J. GREEN
BY
Harold W. Eaton
ATTORNEY

June 14, 1955

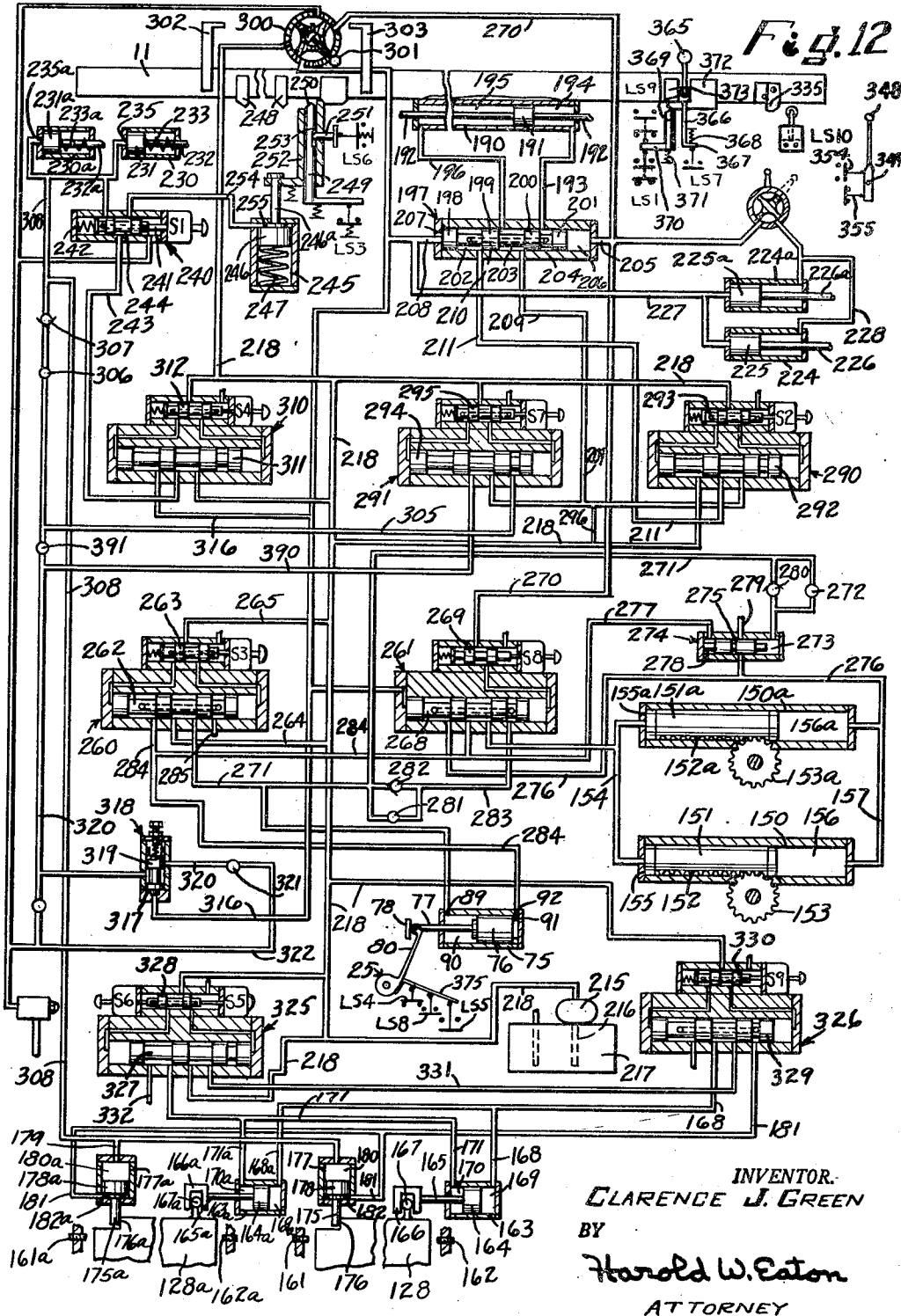
C. J. GREEN

2,710,495

CAM GRINDING MACHINE

Filed Feb. 19, 1953

6 Sheets-Sheet 5



June 14, 1955

C. J. GREEN

2,710,495

CAM GRINDING MACHINE

Filed Feb. 19, 1953

6 Sheets-Sheet 6

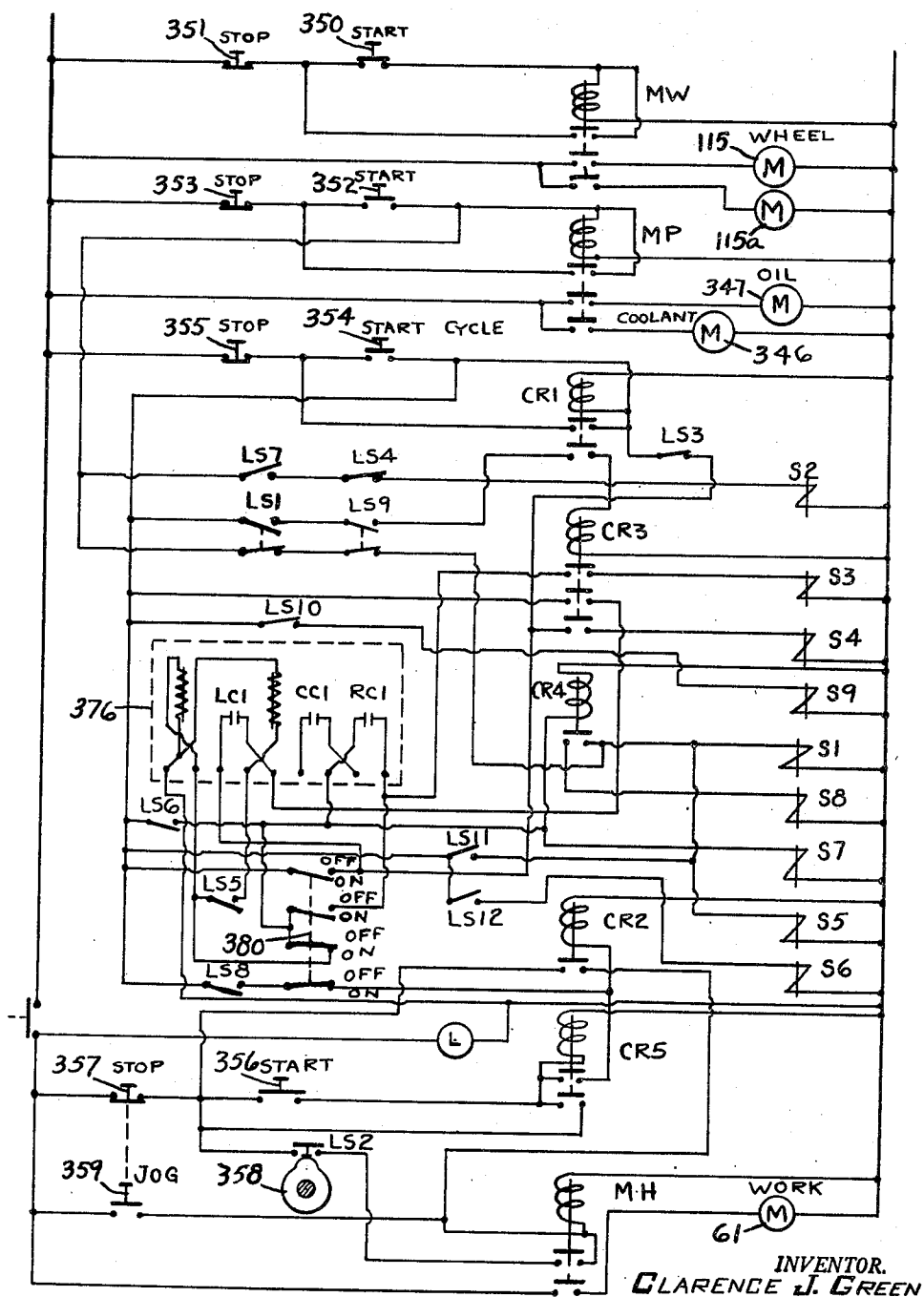


Fig. 13

INVENTOR.
CLARENCE J. GREEN
BY
Harold W. Eaton
ATTORNEY

1

2,710,495

CAM GRINDING MACHINE

Clarence J. Green, Worcester, Mass., assignor to Norton Company, Worcester, Mass., a corporation of Massachusetts

Application February 19, 1953, Serial No. 337,703

9 Claims. (Cl. 51—101)

The invention relates to grinding machines, and more particularly to an automatic cam grinding machine simultaneously to grind a plurality of cam shafts.

One object of the invention is to provide a simple and thoroughly practical automatic cam grinding machine. Another object is to provide a multiple station cam grinding machine whereby the cams on a plurality of cam shafts are simultaneously ground. Another object is to provide a cam grinding machine having a rock bar arranged simultaneously to support a plurality of axially aligned rotatable cam shafts for a grinding operation. Another object is to provide a rock bar with a plurality of axially aligned rotatable cam shaft supports and a single set of master cams and a follower to control oscillation of the rock bar simultaneously to grind corresponding cams on a plurality of camshafts. Another object is to provide a wheel slide swiveling mechanism whereby a plurality of wheel slides may be swiveled simultaneously to position the grinding wheels supported thereby for taper cam grinding. Another object is to provide mechanism whereby a plurality of grinding wheels may be trued simultaneously and the reciprocation of each of the wheel spindles stopped automatically during the truing operation. 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 improved cam grinding machine;

Fig. 2 is a plan view of the cam grinding machine;

Fig. 3 is a right hand end elevation, on an enlarged scale, having parts broken away and shown in section to clarify the construction;

Fig. 4 is a cross sectional view, on an enlarged scale, taken approximately on the line 4—4 of Fig. 2, showing the rock bar and mechanisms associated therewith;

Fig. 5 is a vertical longitudinal sectional view, on an enlarged scale, taken approximately on the line 5—5 of Fig. 2, through the rock bar;

Fig. 6 is a fragmentary plan view of the work head with the cover removed;

Fig. 7 is a fragmentary elevation, on an enlarged scale, of one of the footstocks;

Fig. 8 is a right hand end elevation of the footstock as shown in Fig. 7;

Fig. 9 is a fragmentary front elevation, on an enlarged scale, of the table dog mechanism;

Fig. 10 is a fragmentary view of the table dog mechanism, as shown in Fig. 9;

Fig. 11 is a fragmentary elevation, on an enlarged scale, of the hand wheel for actuating the grinding wheel feeding mechanism;

Fig. 12 is a hydraulic diagram of the control mechanisms of the machine; and

Fig. 13 is an electric wiring diagram of the electric control system of the machine.

A cam grinding machine has been illustrated in the

2

drawings comprising a base 10 which supports a longitudinally movable work table 11. The work table 11 is arranged to slide longitudinally relative to the base 10 on a flat-way 12 and a V-way 13 formed on the upper surface of the base 10.

A manually operable table traversing mechanism is provided comprising a hand traverse wheel 14 (Fig. 3) which is mounted on the left hand end of a rotatable shaft 15. The shaft 15 is provided with a gear 16 meshing with a gear 17 on a rotatable shaft 18. The shaft 18 is provided with a gear 19 which meshes with a rack bar 20 fixedly mounted on the under side of the table 11. It will be readily apparent from the foregoing disclosure that a rotary motion of the hand wheel 14 will be imparted through the mechanism above described to cause a longitudinal traversing movement of the table 11. The direction of rotation of the end wheel 14 serves to determine the direction of movement of the table 11.

The table 11 serves as a support for a rock bar 25 which is journaled in bearings 26, 27 and 28 formed in a bearing bracket 29, a housing 30, and the bearing bracket 31 respectively. For convenience of assembly the rock bar 25 is preferably formed in three parts, namely, 25a, 25b and 25c which are keyed together so as to form an integrally arranged rock bar the axis of which is parallel to the axis of the grinding wheel to be hereinafter described.

The rock bar 25 is provided with a headstock 35 having a headstock center 36. A footstock 37 is also adjustably mounted on the rock bar 25 and is provided with a footstock center 38. The headstock center 36 and the headstock center 38 serve as supports for a cam shaft 39 to be ground. The footstock 37 is arranged so that it may be adjusted longitudinally relative to the rock bar to facilitate positioning the same for different lengths of cam shaft to be ground. The headstock 35 is provided with a headstock spindle 40 which supports the center 36. The spindle 40 is journaled in a bearing 41. A rotatable drive shaft 42 (Fig. 5) is journaled in a bearing 43 carried by the bracket 29 and a spaced bearing 44 formed within the housing 30. The drive shaft 42 is provided with a sprocket 45 which is connected by a cog belt 46 with a sprocket 47 mounted on the headstock spindle 40. The rock bar 25 is also provided with a headstock 50 contained within the housing 30. The headstock 50 is provided with a headstock center 51. The rock bar 25 also adjustably supports a footstock 52 having a footstock center 53. The headstock center 51 and footstock center 53 serves as a support for a cam shaft 54 to be ground. The axis of the headstock center 36 and footstock center 38 are in axial alignment with the headstock center 51 and the footstock center 53.

The headstock 50 is provided with a headstock or master cam spindle 55 which is supported in spaced bearings 56 and 57.

The master cam spindle 55 is provided with a sprocket 58 which is connected by a cog belt 59 mounted on the drive shaft 42. An electric motor 61 is mounted on the table 11 and is provided with a multiple V-groove pulley 62 which is connected by multiple V-belts 63 with a multiple V-groove pulley 64 mounted on the left hand end of the drive shaft 42. It will be readily apparent that when the motor 61 is energized, a synchronous rotary motion will be imparted to the headstock spindle 40 and the master cam spindle 55.

The footstocks 37 and 52 are each provided with a transverse adjustment comprising a dove-tailed slide-way 65 and an adjusting screw 66 by means of which the footstock may be adjusted transversely relative to the rock bar 25 to facilitate aligning the axes of the cam shafts 39 and 54 to be ground.

The master cam spindle 55 supports a plurality of

master cams 67, only two of which have been illustrated in Figs. 5 and 6. There is a master cam 67 for each cam to be ground on the cam shafts 39 and 54. A follower roller 68 is slidably keyed on a rotatable shaft 69 which is journaled in spaced bearings 70 and 71 carried by the housing 30.

A fluid pressure mechanism, comprising a cylinder 75 fixedly mounted within the housing 30 and containing a slidably mounted piston 76, is provided for rocking the rock bar 25 to and from an operative position. It is desirable to rock the rock bar 25 to an inoperative position so as to separate the master cams 67 from the center roller 68 before the table 11 is indexed longitudinally. The piston 76 is connected to one end of a piston rod 77. A U-shaped frame 78 is clamped in a fixed position on the piston rods 77 by means of nuts 79. An upwardly extending arm 80 is fixedly mounted on the rock bar 25. The upper end of the arm 80 is provided with a pair of horizontally extending arms 81 and 82. A pair of tension springs 83 and 84 are connected at one end to the opposite ends of the U-shaped frame 78. The other ends of the springs 83 and 84 are connected by screws 85 and 86 respectively to the arms 81 and 82. By adjusting the screws 85 and 86, the tension of the springs 83 and 84 may be varied as desired. The arms 81 and 82 of the arm 80 are provided with rollers 87 and 88 respectively which are arranged to be engaged by the U-shaped frame 78 when the piston is moved toward the right (Fig. 4). When fluid under pressure is admitted through a port 89 into a cylinder chamber 90 to move the piston 76 toward the right, the U-shaped frame 78 will move into engagement with the rollers 87 and 88 after which continued movement of the piston 76 toward the right will swing the arm 80 in a clockwise direction to impart a clockwise movement to the rock bar 25 thereby separating the master cam 67 from the follower roller 68 during this movement of the piston 76. Fluid is exhausted from a cylinder chamber 91 through a port 92. The screws 85 and 86 are preferably adjusted so that when the piston 76 is at its extreme left hand end position, the tension of the springs 83 and 84 will be sufficient to maintain the master cam 67 in operation with the periphery of the follower roller 68 during rotation of the master cam spindle 55 so as to impart a controlled rocking movement to the rock bar 25 during a cam grinding operation.

As the piston 76 moves toward the right, to shift the rock bar 25 to an inoperative position, the U-shaped frame 78 moves toward the right and due to the clearance between the frame 78 and the rollers 87 and 88 relieves the tension of the springs 83 and 84. During movement of the piston 76 and frame 78 toward the right, the frame 78 engages the rollers 87 and 88 and rocks the arm 80 and rock bar 25 to an inoperative position. By utilizing this construction, the extending and contracting of the springs 83 and 84 is reduced to a minimum. During movement of the piston 76 toward the left (Fig. 4), the master cam 67 engages the follower roller 68 after which the continued movement of the frame 78 toward the left separates the frame 78 from the rollers 87 and 88 and increases the tension on the springs 83 and 84 respectively to the desired operating tension.

A suitable indexing mechanism is provided which is actuated by and in timed relation with the indexing movement of the work table for indexing the master cam roller 68 longitudinally to position it in relationship with the master cam corresponding with the cam to be ground. This mechanism may be substantially the same as that shown in U. S. Patent No. 1,783,755 to C. G. Trefethen et al. dated December 2, 1930, to which reference may be had for details of disclosure not contained herein. A bracket 99 fastened to the base 10 (Figs. 3 and 4) serves as a support for a dog bar 100 having a plurality of adjustable dogs 101 mounted thereon.

The dogs 101 are arranged in the path of movement of a star wheel 102 carried at the lower end of a shaft 103. The upper end of the shaft 103 is provided with a gear 104 which meshes with a gear 105 carried by a shaft 106. The shaft 106 also supports a gear 107 which meshes with a longitudinally slidable rack bar 108 supported within the housing 30. A yoked member 109 is fastened to the rack bar 108 and engages the side faces of the follower roller 68. It will be readily apparent from the foregoing disclosure that when the table 11 is moved longitudinally, the star wheel 102 engaging adjustable dogs 101 will impart an indexing movement through the gearing above described to index the master cam roller longitudinally to position it opposite the master cam 67 corresponding to the cam on the cam shafts 39 and 54 to be ground.

The base 10 serves as a support for a transversely movable wheel slide 110. The wheel slide 110 is supported on spaced ways, such as a flat way 111 and a V-way 112. The wheel slide 110 supports a wheel spindle 113 in bearings (not shown). A grinding wheel 114 is mounted on the right hand end of the wheel spindle 113 (Figs. 1 and 2).

A suitable driving mechanism is provided for the wheel spindle 113 comprising a motor 115 adjustably supported on the upper surface of the wheel slide 110. The motor is provided with a motor shaft supporting a multiple V-groove pulley 117. The pulley 117 is connected by multiple V-belts 118 with a multiple V-groove pulley 119 mounted on the left hand end of the wheel spindle 113. The electric motor 115 is preferably supported on a platen 120 which is adjustably mounted on the wheel slide. An adjusting screw 121 is provided to facilitate a transverse adjustment of the platen 120 relative to the wheel slide 110 to facilitate adjusting the motor 115 to tension the driving belts 118 as desired. The wheel slide 115 is positioned on the base 10 for bringing the grinding wheel 114 successively to grind the cams on the cam shaft 54.

A second wheel slide 110a is also supported on the base 10 on a flat way 111a and a V-way 112a. The wheel slide 110a supports a rotatable wheel spindle 113a in suitable bearings (not shown) within the wheel slide 110. A grinding wheel 114a is mounted on the right hand end of the wheel spindle 113a. The wheel slide 110a and the grinding wheel 114a are positioned on the base 10 so that the grinding wheel 114a will grind a corresponding cam on the cam shaft 39.

A suitable driving mechanism is provided comprising a motor 115a supported on the upper surface of the wheel slide 110a. The motor 115a is provided with a motor shaft 116a carrying a multiple V-groove pulley 117a. The pulley 117a is connected by multiple V-belts 118a with a multiple V-groove pulley 119a on the left hand end of the wheel spindle 113a. The motor 115a is supported on a motor platen 120a which is adjustably supported on the wheel slide 110a. An adjusting screw 121a is provided to facilitate a transverse adjustment of the motor platen 120a and the motor 115a to facilitate proper tensioning of the driving belts 118a.

A suitable feeding mechanism is provided for feeding the grinding wheel slides 110 and 110a transversely successively to grind corresponding cams on the cam shafts 54 and 39 respectively. These feeding mechanisms are identical in construction, consequently only the feeding mechanism for the wheel slide 110 has been illustrated and will be described in detail. This mechanism may comprise a rotatable feed screw 125 which is journaled in anti-friction bearings 126 and 127. The bearings 126 and 127 are fixedly supported on a wheel slide base 128.

A nut 129 surrounds the feed screw 125 and is supported in spaced anti-friction bearings 130 and 131 carried within a housing 132. The housing 132 is fixedly mounted on the underside of the wheel slide 110 (Fig. 3).

A manually operable mechanism is provided for imparting a rotary motion to the feed screw 125. This

mechanism may comprise a feed wheel 133 mounted on the left hand end of a rotatable shaft 134 which is supported within a housing 135 mounted on the upper portion of the wheel slide 110. The shaft 134 carries a bevel gear 136 which meshes with a bevel gear 137 mounted on the upper end of a vertically arranged rotatable shaft 138. The shaft 138 is connected by a coupling 139 with the upper end of a vertically arranged rotatable shaft 140. The lower end of the shaft 140 is provided with a bevel gear 141 which meshes with a bevel gear 142 slidably keyed on a horizontally arranged shaft 143. The shaft 143 is connected by a clutch with the feed screw 125. The shaft 143 supports a clutch member 144 having an internal gear formed thereon which is arranged to mesh with an external gear 145. The gear 145 is mounted on a rotatable sleeve 146 which is rotatably supported on a shaft 143. The shaft 143 is provided with a gear 148 which meshes with a gear 149 slidably keyed onto the feed screw 125. It will be readily apparent that a rotary motion of the hand wheel 133 will be mounted through the mechanism above described to rotate the feed screw 125 to impart a transverse feeding movement to the grinding wheel 114. The gear 149 is preferably connected to the housing 132 so that the gear 149 will be moved longitudinally relative to the feed screw 125 when the wheel slide 110 is fed transversely in either direction. The direction of rotation of the feed wheel 133 serves to determine the direction of movement of the slide 110 relative to the base 10.

It is desirable to provide a power operated mechanism for feeding the grinding wheel slide 110. This mechanism may comprise a fluid pressure cylinder 150 which is supported on the upper portion of the wheel slide 110 (Figs. 2, 3, and 12). The cylinder 150 contains a slidably mounted piston 151 having a rack 152 formed integrally therewith. The rack 152 meshes with a gear 153 which is fixedly mounted on the sleeve 146. It will be readily apparent that an endwise movement of the piston 151 will be transmitted through the rack 152, the gear 153 to rotate the gear 148, the gear 149 to impart a rotary motion to the feed screw 125.

When fluid under pressure is passed through a pipe 154 (Fig. 12) into a cylinder chamber 155, the piston 151 will be moved toward the right to impart a clockwise rotation to the gear 153 (Fig. 12) so as to impart a rotary motion to the feed screw 125 to cause an infeeding movement of the grinding wheel 114. During this movement fluid within a cylinder chamber 156 is exhausted through a pipe 157. Similarly when fluid under pressure is passed through the pipe 157 into the cylinder chamber 156, the piston 151 will be moved toward the left (Fig. 12) to impart a counter-clockwise rotation to the gear 153 thereby rotating the feed screw 125 so as to cause a rearward movement of the wheel slide 110 and the grinding wheel 114.

A positive stop mechanism is provided to positively limit the infeeding movement of the wheel slide 110 when actuated either manually by rotation of the hand wheel 113 or by movement of the piston 151. This mechanism comprises a stop pawl 122 which is pivotally supported by a stud 123. The stop pawl 122 is arranged in the path of an adjustably mounted abutment 124 carried by the feed wheel 133.

An identical feeding mechanism is provided for the wheel slide 110a comprising a manually operable feed wheel 133a and a stop pawl 122a. The details of the nut and screw feed are identical with those just described in connection with the feed mechanism for the slide 110, consequently they will not be illustrated or described in connection with the feed mechanism for the wheel slide 110a. A fluid pressure cylinder 150a is provided for actuating the feed screw by power. The cylinder 150a contains a slidably mounted piston 151a having a rack 152a formed integrally therewith. The rack 152a meshes with a gear 153a which is operatively connected to im-

part a rotary motion to the feed screw (not shown). When fluid under pressure is passed through a pipe 154 into a cylinder chamber 155a, the piston 151a will be moved toward the right so as to impart a clockwise movement to the gear 153a thereby imparting a rotary motion to the feed screw (not shown) so as to cause a receding movement of the wheel slide 110a. Similarly when fluid under pressure is passed through the pipe 157 into the cylinder chamber 156a, the piston 151a will be moved toward the left so as to impart a counter-clockwise motion to the gear 153a thereby causing a transverse movement of the wheel slide 110a to an inoperative position.

As illustrated in Fig. 12, the power operated feeding mechanisms are arranged so that both of the wheel slides 110 and 110a are simultaneously moved toward or from the cam on the cam shafts 54 and 39 to be ground. When fluid under pressure is passed through the pipe 154 into the cylinder chambers 155 and 155a, the pistons 151 and 151a will be simultaneously moved toward the right to cause a simultaneous infeeding movement to be imparted to the wheel slides 110 and 110a respectively. Similarly when fluid under pressure is passed through the pipe 157 into the cylinder chambers 156 and 156a, the pistons 151 and 151a will be moved toward the left into the positions illustrated in Fig. 12 to cause a simultaneous movement of the wheel slides 110 and 110a to a rearward or inoperative position.

A secondary feeding mechanism is provided for advancing both of the wheel slides for a truing operation so as to compensate for wheel wear and to feed the wheels by an amount to be trued therefrom. These mechanisms may comprise a feed compensator 220 mounted on the upper surface of the wheel slide 110 and a feed compensator 220a mounted on the upper surface of the wheel slide 110a (Fig. 2). The feed compensators are arranged to impart a rotary motion to a vertical shaft 221 (Fig. 3) which is provided by its lower end with a worm 222 which meshes with a worm gear 223 formed on the periphery of the feed nut 129. It will be readily apparent that a rotary motion of the shaft 121 will impart a rotary motion to the nut 129 to cause an advancing movement of the slide 110 so as to compensate for wheel wear and truing. The feed compensator 220 contains a fluid pressure cylinder 224 having a slidably mounted piston 225 contained therein. The piston 225 is connected to one end of a piston rod 226 which is connected through a rack and gear mechanism (not shown) to rotate the shaft 221. When fluid under pressure is passed through a pipe 227 (Fig. 12), the piston 225 is moved toward the right. During this movement fluid within the other end of the cylinder 224 may exhaust through a pipe 228. This feed compensator is identical with that shown in the prior U. S. patent to C. J. Green and O. E. Hill No. 2,535,130 dated December 26, 1950, to which reference may be had for details of disclosure not contained herein.

Similarly the feed compensator 220a is provided with a cylinder 224a having a slidably mounted piston 225a which is connected to one end of a piston rod 226a. Fluid under pressure passing through either the pipe 227 or the pipe 228 simultaneously enters both of the cylinders 224 and 224a simultaneously to impart a compensating movement to the wheel slides 110 and 110a.

It is desirable to provide a suitable mechanism for swivelling the wheel slides 110 and 110a in a horizontal plane to facilitate grinding tapered surfaces on the cams being ground. This is preferably accomplished in a manner substantially identical with that shown in my prior U. S. Patent No. 2,581,759 dated January 8, 1952, to which reference may be had for details of disclosure not contained herein. As illustrated in Fig. 2, the wheel slide 128 is arranged to pivot about a vertical stud 160. Similarly the wheel slide base 128a is arranged to pivot about a stud 160a. The axis of the studs 160 and 160a are preferably located with their axes in a mid-plane be-

tween the side faces of the grinding wheels 114 and 114a.

The wheel slide base 128a is limited in its swinging movement by means of a pair of adjustable stop screws 161 and 162 which are supported by the base 10. A fluid cylinder 163 is mounted in the rear of the base 10. The cylinder 163 contains a slidably mounted piston 164 which is connected to one end of a piston rod 165 (Fig. 12). The other end of the piston rod 165 is provided with a yoke 166 which engages a rearwardly projecting stud 167 fixedly mounted on the wheel slide base 128. When fluid under pressure is passed through a pipe 168 into a cylinder chamber 169, the piston 164 will be moved toward the left to swing the wheel slide base 128 together with the wheel slide 110 and the grinding wheel 114 in a counter-clockwise direction. The swinging movement will continue until the wheel slide base 128 engages the stop screw 161. During this movement of the piston 164 fluid within a cylinder chamber 170 may exhaust through a pipe 171. Similarly when the direction of flow of fluid under pressure is reversed and fluid under pressure is passed through the pipe 171 into the cylinder chamber 170, the piston 164 will be moved toward the right to swing the wheel slide base 128, the wheel slide 110 and the grinding wheel 114 in a clockwise direction until the wheel slide base 128 engages the stop screw 162. By adjusting the position of the stop screws 161 and 162, the amount of swivel can be varied so that the periphery of the grinding wheel 114 will grind the desired and predetermined taper on the cam being ground.

In order to facilitate a grinding wheel truing operation, it is desirable to position the wheel slide base 128 together with the wheel slide 110 and the grinding wheel 114 in a central position so that the axis of the wheel spindle 113 is parallel to the path of movement of the work table 11 so that the operative face of the grinding wheel 114 may be trued by means of a truing tool 159 mounted on the table 11. In order to facilitate positioning the wheel slide base 128 in a central position, a hydraulically operated mechanism is provided comprising a cylinder 177 which contains a slidably mounted piston 178. The piston 178 is connected to one end of a piston rod 175 which serves as a stop stud which may be moved into or out of the path of a stop surface 176 formed on the wheel slide base 128. When fluid under pressure is passed through a pipe 179 into a cylinder chamber 180, the piston 178 will be moved into the position illustrated in Fig. 12. During this movement of the piston 178 fluid within a cylinder chamber 182 may exhaust through a pipe 181. When the flow of fluid under pressure is reversed and fluid is passed through the pipe 181 into the cylinder chamber 182, the piston 178 will be moved upwardly (Fig. 12) to withdraw the piston rod 175 out of the path of the stop surface 176, in which position the wheel slide base is free to swivel in either direction for a grinding operation.

A similar mechanism is provided for controlling the swivelling movement of the wheel slide base 128a, the wheel slide 110a and the grinding wheel 114a. This mechanism may comprise a pair of adjustable stop screws 161a and 162a supported on the base 10, a cylinder 163a mounted on the base 10 contains a slidably mounted piston 164a having a piston rod 165a which is connected by a yoked member 166a with a stud 167a projecting from the rear surface of the wheel slide base 128a. When fluid under pressure is passed through a pipe 168a into a cylinder chamber 169a, the piston 164a will be moved toward the left so as to impart a counter-clockwise swivelling movement to the wheel slide base 128a, the wheel slide 110 and the grinding wheel 114a. Similarly when fluid under pressure is passed through a pipe 171a into a cylinder chamber 170a, the piston 164a will be moved toward the right so as to impart a clockwise swivelling movement to the wheel slide base 128a.

A similar fluid operated stop mechanism is provided

for locating the wheel slide base 128a in a central position for a truing operation. This mechanism comprises a cylinder 177a which contains a slidably mounted piston 178a having a piston rod 175a which serves as a stop which may be moved into or out of the path of movement of a stop surface formed on the wheel slide base 128a. When fluid under pressure is passed through the pipe 179 it is conveyed simultaneously to the cylinder chambers 180 and 180a to move the stop pins 175 and 175a into an operative position as illustrated in Fig. 12. Similarly when fluid under pressure is passed through the pipe 181 it is simultaneously passed into the cylinder chambers 182 and 182a to withdraw the stop studs 175 and 175a.

A hydraulically operated table indexing mechanism is provided for entering the work table 11 longitudinally successively to position cams on the cam shafts 54 and 39 to be ground. This mechanism may comprise a cylinder 190 which is fixedly mounted to the underside of the table 11. The cylinder 190 contains a slidably mounted piston 191 which is connected to a double end piston rod 192 the opposite ends of which are fixedly mounted to brackets 189 and 189a fixedly mounted on the base 10. When fluid under pressure is passed through a pipe 193 into a cylinder chamber 194, the cylinder 190 and the table 11 will be caused to move toward the right. During this movement, fluid within a cylinder chamber 195 may exhaust through a pipe 196. Similarly when fluid under pressure is passed through the pipe 196 into the cylinder chamber 195, the cylinder 190 together with the table 11 will be moved toward the left.

A shuttle type control valve 197 is provided for controlling the flow of fluid to the cylinder 190. The valve 197 contains a slidably mounted valve member having a plurality of integral valve pistons 198, 199, 200 and 201 forming a plurality of valve chambers 202, 203 and 204. When fluid under pressure is passed through a pipe 205 into an end chamber 206, the valve 197 is shifted into a left hand end position. During this movement fluid within the end chamber 207 may exhaust through a pipe 208. In the position of the valve 197 (Fig. 12) fluid under pressure passing through a pipe 209 enters the valve chamber 203 and passes through the pipe 196 into the cylinder chamber 195 to cause the cylinder 190 together with the table 11 to move toward the left. During this movement fluid within the cylinder chamber 194 may exhaust through the pipe 193 into the valve chamber 204 through a central passage 210 formed within the slidable member of the valve 197 into the valve chamber 202 and out through an exhaust pipe 211.

When fluid under pressure is passed through the pipe 208, the slidable valve member of the valve 197 is shifted toward the right so that fluid under pressure from the pipe 209 entering the valve chamber 203 passes through the pipe 193 into the cylinder chamber 194 to cause the cylinder 190 together with the table 11 to move toward the right.

A wheel spindle reciprocating mechanism is provided within each of the wheel slides 110 and 110a for reciprocating the wheel spindles 113 and 113a respectively axially within their bearings during a grinding operation. This mechanism has not been illustrated in detail since it is an old and well known mechanism used in most grinding machines where a plunge-cut grinding operation is obtained. For details of disclosure not contained herein, reference may be had to the prior U. S. Patent No. 2,237,496 to G. T. Muskovin dated April 8, 1941. It is desirable to stop the wheel spindle reciprocation during a grinding wheel truing operation. To accomplish this result a cylinder 230 (Fig. 12) is provided. The cylinder 230 contains a slidably mounted piston 231 connected to one end of a piston rod 232. The piston rod 232 is operatively connected to stop oscillation of the wheel spindle when desired. A compression spring 233 contained within the cylinder 230 serves normally to

hold the piston 231 in a left hand end position except when fluid under pressure is admitted through a pipe 234 into the cylinder chamber 235 to cause movement of the piston 231 toward the right to stop the reciprocation of the wheel spindle. A similar mechanism is provided for controlling the reciprocation of the wheel spindle 113a. This mechanism may comprise a cylinder 230a, a piston 231a, a piston rod 232a, a spring 233a arranged in the same manner as previously described. When fluid under pressure is passed through the pipe 234 it passes simultaneously into the cylinder chambers 235 and 235a simultaneously to stop reciprocation of the wheel spindles 113 and 113a respectively.

A valve 240 serves when the solenoid S1 is deenergized to admit fluid under pressure to a table index cylinder 245. The valve 240 is a piston type valve having a valve stem 241 which is normally held in a right hand end position by a compression spring 242. A fluid pressure pipe 243 conveys fluid to a valve chamber 244. When the solenoid S1 is energized, fluid entering the valve chamber 244 passes through the pipe 234 to both of the cylinders 230 and 230a to stop wheel spindle reciprocation.

The table index cylinder 245 is provided with a slidably mounted piston 246. A spring 247 normally serves to hold the piston 246 in an upper motion position. In the position of valve 240 (Fig. 12) fluid under pressure entering the valve chamber 244 passes through a pipe 254 into a cylinder chamber 255 to cause a downward movement of the piston 246. The piston 246 is connected by a piston rod 246a with a plunger 252. A plunger 249 is slidably mounted with a central aperture in the plunger 252. When the piston moves downwardly, the plunger 252 also moves downwardly and a cam face 253 on a plunger 249 actuates a plunger 251 to close a normally open limit switch LS6. The upper end of the plunger 249 is provided with an arrow point 250 which is arranged in the path of a plurality of table index dogs 248. The downward movement of the plunger 249 serves to open a normally closed limit switch LS3.

A fluid pressure system is provided for supplying fluid under pressure to operate the various mechanisms of the machine comprising a motor driven fluid pump 215 which draws fluid through a pipe 216 from a reservoir 217 and passes fluid under pressure through a pipe 218 to the various mechanisms of the machine. A control valve 260 and a control valve 261 are provided to control the admission to and exhaust of fluid from the wheel feed cylinders 150 and 150a. The valve 260 is a shuttle type valve comprising a movable valve member 262 having a plurality of valve pistons formed integral therewith. The valve member 262 is arranged to be shifted by fluid under pressure controlled by a pilot valve 263 which is actuated by a solenoid S3 (Fig. 12). Fluid under pressure is passed through a pipe 264 from the pressure pipe 218 and also through a pipe 265 to the solenoid actuated pilot valve 263. In the position of the valve 263 (Fig. 11) fluid under pressure is admitted from the pilot valve to an end chamber in the right hand end of the control valve 260 to move the valve member 262 toward the left.

The valve 261 is similarly a shuttle type valve comprising a slidably mounted valve member 268 the movement of which is controlled by a pilot valve 269 actuated by a solenoid S8. Fluid under pressure is passed through a pipe 270 into a valve chamber formed at the right hand end of the valve 261 to shift the valve member 268 to its left hand end position.

In the position of the valves 260 and 261 as illustrated in Fig. 12, fluid under pressure passing through the pipe 264, passes through a pipe 271, through a needle valve 272 into a right hand end chamber 273 formed in a backlash control valve 274. The backlash control valve 274 is a piston type valve comprising a pair of spaced valve pistons forming a valve chamber 275. During the

initial feeding movement of the grinding wheel, fluid exhausting from the cylinder chambers 156 and 156a exhausts through a pipe 276. During this exhaust of fluid from the cylinder chambers 156 and 156a, fluid under pressure is admitted through a pipe 277 into a left hand end chamber 278 of the backlash valve 274 to shift the valve toward the right at a rate controlled by the needle valve 272. During this shifting movement of the backlash valve 274, the valve chamber 275 passing over a port formed in the pipe 276 allows a predetermined amount of fluid to exhaust from the pipe 276 through the valve chamber 275 and out through an exhaust pipe 279 into the reservoir 217. The speed of movement of the valve 274 as controlled by the throttle valve 272 governs the amount of fluid permitted to exhaust from the pipe 276. This exhaust of fluid is in addition to the regular controlled exhaust of fluid from the cylinder chambers 156 and 156a and serves to provide an initial rapid movement of the feed pistons 151 and 151a to take up backlash in the feeding mechanism. A ball check valve 280 is provided in the pipe line 271 so that when fluid under pressure is passed through the pipe 271 it may pass substantially unrestricted into the end chamber 273 to cause a rapid return movement of the valve 274 into its left hand end position.

Fluid under pressure passing through the pipe 271 may also pass through a throttle valve 281 which controls the normal rate of movement of the feed pistons 151 and 151a in a manner to be hereinafter described. Fluid under pressure passing through the pipe 271 may also open a ball check valve 282 and pass substantially unrestricted through a pipe 283 into the valve 261. Fluid under pressure passing through the pipe 283 into the valve 261 passes through a central passage in the slidable valve member 268 and out through the pipe 276 into the cylinder chambers 156 and 156a to cause the pistons 151 and 151a to move toward the left. Movement of the pistons 151 and 151a toward the left serves through a gear mechanism above described to rotate the feed wheels 133 and 133a and the feed screws 125 and 125a to move the grinding wheels 114 and 114a and the supporting wheel slides 110 and 110a rearwardly to an inoperative position. During movement of the pistons 151 and 151a toward the left fluid exhausting through the pipe 154 passes through the valve 261 and out through a pipe 284 into the valve 260, through a central passage formed in the slidable valve member 262 and out through an exhaust pipe 285 into the reservoir 217.

A pair of control valves 290 and 291 are provided to control the admission to and exhaust of fluid from the shuttle valve 197 and to the table cylinder 190. The control valves 290 and 291 are substantially identical with the valves 260 and 261 and therefore have not been shown except diagrammatically in Fig. 12. The control valve 290 comprises a shuttle type slidably mounted valve member 292 and a pilot valve 293 which is actuated by a solenoid S2. Fluid under pressure from the pump 215 passing through the pipe 218 enters the pilot valve 293 and passes through a passage into the valve 290 to shift the valve into the left hand end position. Similarly the valve 291 comprises a slidably mounted valve member 294 which is preferably a shuttle type valve the position of which is controlled by a pilot valve 295. The pilot valve 295 is actuated by a solenoid S7.

A small pipe 296, of approximately one-eighth inch in diameter connects the pipe 218 with the pipe 209 which serves when the valve 200 is positioned as shown in Fig. 12 to pass a small quantity of fluid under pressure through both of the pipes 209 and 211, through the shuttle type valve 97 into the cylinder chambers 194 and 195 to balance the pressure on opposite sides of the piston 191 so as to hold the table 11 stationary. When the solenoid S2 is energized so as to admit

fluid under pressure to the valve chamber in the left hand end of the valve 290 to move the valve member 292 toward the right, fluid under pressure from the pipe 218 passes through the valve 290, through the pipe 211, through the shuttle valve 197 and through the pipe 193 into the cylinder chamber 194 to cause the table 11 to move toward the right.

Similarly when the shuttle valve 197 is moved toward the right into an extreme right hand end position, fluid under pressure passing through the pipe 211 passes through the pipe 196 into the cylinder chamber 193 to cause the cylinder 190 and the table 11 to move toward the left. It will be readily apparent from the foregoing disclosure that when the solenoid S2 is energized, the valve 290 will be positioned to control the admission of fluid through the pipe 211 to the shuttle valve 197 and the table cylinder 190. When the solenoid S2 is deenergized, the valve 290 is positioned as shown in Fig. 12 to facilitate bypassing of fluid between opposite ends of the cylinder 190 to facilitate a manual traversing of the table 11. A reversing valve 300 actuated manually by means of a handle 301 serves normally to reverse the direction of flow of fluid to the opposite ends of the shuttle valve 197. The valve 300 may also be actuated automatically by and in timed relation with the longitudinal movement of the table 11 by a pair of reversing dogs 302 and 303.

Fluid exhausting through a pipe 305 during the normal table indexing movement may pass through a throttle valve 396 which serves to control the normal indexing speed of the table 11 and passes through a ball check valve 307, through a pipe 308 into the control valve 240 which is actuated by the solenoid S1. When solenoid S1 is energized and the valve member 241 is in its extreme left hand end position fluid passing from the pipe 308 may pass through the pipe 243 to a control valve 310. The control valve 310 is substantially identical with control valves 260 and 261 and comprises a slidably mounted valve member 311, and a pilot valve 312 which is actuated by a solenoid S4. When the solenoid S4 is deenergized as shown in Fig. 12 fluid under pressure from the pipe 218 passes through the valve 310, through the pipe 243 to the control valve 240. In the position of the control valve 240 (Fig. 12), fluid under pressure in the pipe 243 passes through the pipe 254 into the cylinder chamber 255 to move the piston 246 downwardly against the compression of the spring 245 to withdraw the plungers 249 and 252 out of the path of the table dogs 248. When the solenoid S1 is energized, fluid under pressure from the pipe 243 may pass through the pipe 234 into the cylinder chambers 235 and 235a to move the pistons 231 and 231a so as to stop wheel spindle reciprocation.

When the solenoid S4 is energized, fluid exhausts through a pipe 316 from the reversing valve 300 also passes into a chamber 317 formed at the lower end of a spring press valve 318. Pressure entering the valve chamber 317 raises a valve member 319 so that fluid within a pipe 320 may exhaust through a chamber in the valve 318 and pass out through a pipe 320, through a throttle valve 321, through a pipe 322, into the reservoir 217. The valve 318 is operative during the idle return stroke of the table 11 to facilitate a rapid return stroke so that fluid instead of having to pass through the throttle valve 306 may pass directly through the spring press valve 318 and the throttle valve 321 into the reservoir. The throttle valve 321 serves to regulate fluid exhausting through the valve 318 so that the return of the idle stroke may be readily adjusted.

A pair of control valves 325 and 326 are provided for controlling the admission to and exhaust of fluid from the cylinders 163 and 163a respectively for controlling the swivelling movement of the wheel slide bases 128 and 128a. The control valve 325 comprises a slidably mounted valve member 327 and a pilot valve 328 which

is actuated by a pair of solenoids S5 and S6. The control valve 326 comprises a slidably mounted valve member 329, and a pilot valve 330 which is actuated by means of a solenoid S9. In the position of the valves 325 and 326 (Fig. 12) fluid under pressure from the pipe 218 passes through the valve 325, through a pipe 331, through the control valve 326 and through the pipe 168 and 168a into cylinder chambers 169 and 169a so as to cause the pistons 164 and 164a to move toward the left thereby imparting a counter-clockwise swivelling movement to the wheel slide bases 128 and 128a. During this movement fluid within the cylinder chambers 170 and 170a may exhaust through the pipes 171 and 171a, through the valve 325 and through an exhaust pipe 332 into the reservoir 217. When the solenoid S5 is deenergized and the solenoid S6 is energized, the valve member 327 shifts to the left hand end position so that fluid under pressure from the pipe 218 passes through the pipes 171 and 171a into the cylinder chambers 170 and 170a to cause the pistons 164 and 164a to move toward the right so as to impart a clockwise swivelling movement to the wheel slide bases 128 and 128a.

The solenoid S9 is energized momentarily by an adjustable table dog 335 which momentarily closes a normally open limit switch LS10 when movement of the table 11 is started toward the right at the start of the grinding cycle, to shift the valve member 329 toward the right so that fluid under pressure passing through the pipe 331 from the valve 325 will pass through the pipes 181 and 181a into the cylinder chambers 182 and 182a respectively so as to withdraw the stop plungers 175 and 175a to an inoperative position. The limit switch LS10 opens immediately after the dog 335 passes over the actuating roller to deenergize the solenoid S9 so that the valve member 329 shifts toward the left into the position illustrated in Fig. 12 thereby passing fluid under pressure through the pipes 168 and 168a to cause the pistons 164 and 164a to move toward the left thereby swivelling the wheel slide bases 128 and 128a in a counter-clockwise direction into engagement with the stop screws 161 and 161a. This swivelling movement serves to position the grinding wheels 114 and 114a in position to grind a taper on the first cam on the cam shafts 54 and 39 which tapers toward the left.

When the table is indexed longitudinally toward the right to position the second cam on the shafts 54 and 39 opposite the grinding wheels 114 and 114a respectively, a table dog 336 closes a normally open limit switch LS12 to energize solenoid S6 so as to shift the valve member 327 toward the left thereby passing fluid under pressure through the pipes 171 and 171a into the cylinder chambers 170 and 170a to move the pistons 164 and 164a respectively toward the right thereby swinging the wheel slide bases 128 and 128a in a clockwise direction into engagement with the stop screws 162 and 162a respectively. This swivelling movement of the wheel slide bases 128 and 128a serves to swivel the grinding wheel slides 110 and 110a and the grinding wheels 114 and 114a to position the operative faces of the wheels for grinding an opposite taper on the second cam on the cam shaft.

Similarly when the table is next indexed toward the right to position the third cam on the shafts 54 and 39 in operative relation with the grinding wheels 114 and 114a, a table dog 337 closes a normally open limit switch LS11 to energize the solenoid S5 thereby shifting the valve member 327 into the position illustrated in Fig. 12 so that fluid under pressure is passed through the pipe 331 to the valve 326, and through the pipes 168 and 168a to cause the pistons 164 and 164a to move toward the left thereby imparting a counter-clockwise swivelling movement to the wheel slide bases 128 and 128a. This movement serves to position the grinding wheels 114 and 114a to grind an opposite taper on the third cam on the cam shafts 54 and 39. As shown in Fig. 2, the ma-

chine is set up to grind alternate cams on the cam shafts 54 and 39 which taper in opposite directions.

A plurality of dogs corresponding with dogs 336 and 337 are provided for imparting a swivelling movement to the wheel slide bases 128 and 128a each time the table 11 is indexed toward the right to position a cam for a grinding operation. This mechanism is identical with that shown in my prior U. S. Patent No. 2,581,759 dated January 8, 1952, to which reference may be had for details of disclosure not contained herein. During the idle stroke of the table 11 toward the left, the dogs 336 and 337 ride idly over the limit switches LS12 and LS11 respectively.

When the table 11 moves into position for a grinding wheel truing operation, the solenoid S1 is energized so that fluid under pressure from the pipe 243 will pass through the pipe 234 into cylinder chambers 235 and 235a to stop the axial reciprocation of the wheel spindles 113 and 113a respectively. Fluid under pressure passing through the pipe 234 passes also through the pipe 308 into the cylinder chambers 180 and 180a to move the stop plungers 175 and 175a into operative positions as shown in Fig. 12. The wheel slide bases 128 and 128a are positioned in clockwise positions for grinding the taper on the left cam shaft. After the stop plungers 175 and 175a are moved to an operative position, fluid is passed through the pipe 168 into cylinder chambers 169 and 169a to swivel the wheel slide bases 128 and 128a in a counterclockwise direction. The clockwise swivelling movement continues until the stop surfaces 176 and 176a move into engagement with the stop plungers 175 and 175a respectively to position the grinding wheel spindle into a position parallel with the table 11 so that a truing operation may be obtained. The rock bar 25 is provided with a pair of adjustably mounted diamonds or truing tools 195 and 195a which are positioned so that the traversing movement of the table 11 will pass the truing tools 195 and 195a across the periphery of the grinding wheels 114 and 114a to true cylindrical surfaces thereon. This truing arrangement is likewise identical with that shown in my prior patent above referred to.

As previously mentioned the table 11 also is provided with a plurality of table index dogs 248 which serve precisely to position the table in successive grinding positions with successive cams positioned opposite the grinding wheels 114 and 114a. This table indexing mechanism is identical with that disclosed in the prior U. S. Patent to C. J. Green and O. E. Hill No. 2,535,130 dated December 26, 1950 to which reference may be had for details of disclosure not contained herein.

A cycle control lever 348 is pivotally mounted on the stud 349 on the front of the machine base. The cycle control lever 348 is arranged when rocked in a counterclockwise direction (Fig. 12) to close a normally open cycle start switch 354. When the lever 348 is rocked in a clockwise direction, a normally closed cycle stop switch 355 is opened.

As shown in Fig. 13 a normally open start switch 350 is provided for starting the grinding wheel driving motors 115 and 115a. A normally closed stop switch 351 is provided for stopping the wheel driving motors 115 and 115a when desired. A normally open start switch 352 is provided for starting a motor 347 for driving the fluid pump 215. A normally closed stop switch 353 is provided to facilitate stopping the motor 347 when desired.

A normally open start switch 356 is provided for starting the work driving motor 61. A normally closed stop switch 357 is provided for stopping the motor 61 when desired. A stop control mechanism is provided for stopping the rotation of the work piece in a predetermined position which includes a cam 358 which is arranged to open a limit switch LS2 to stop the motor 61 with the work piece in a predetermined position. A jog switch 359 is provided to facilitate jogging the motor 61 in setting up the machine.

A main control lever 365 is mounted on the upper end of a vertically arranged shaft 366. The lower end of the shaft 366 is provided with an actuating arm 367 which is arranged to engage an actuating plunger for actuating a limit switch LS7. A compression spring 368 serves normally to hold the limit switch LS7 open. A vertically arranged plunger 369 having an arrow-pointed upper end carries a laterally projecting arm 370 at its lower end. The arm 370 is arranged to actuate a pair of limit switches LS1 and LS9 when the plunger 369 is moved in a vertical direction. A compression spring 371 serves normally to hold the plunger 369 in an upper-most position. As the table 11 is moved longitudinally, a dog 372 on the table 11 engages the arrow point on the plunger 369 to depress the plunger 369 so as to actuate both the limit switch LS1 and the limit switch LS9. A rotary motion of the main control lever 365 serves to move a projecting stud 372 to actuate and open the normally closed limit switch LS7 in a manner to be hereinafter described. This mechanism is substantially the same as that shown in the 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.

Operation

The operation of the improved Cam-O-Matic grinding machine will be readily apparent from the foregoing disclosure. Assuming all of the parts and mechanisms to have been previously adjusted for grinding a plurality of cam blanks on the cam shafts 54 and 39, a main power switch (not shown) is closed to render the electric circuits operative. When the main switch is closed, the solenoid S1 is energized (the solenoid S4 being deenergized) so that fluid passes through the pipes 243 and 308. The start switch 350 is then actuated to start the grinding wheel driving motors 115 and 115a. The start switch 352 is then actuated to start both the hydraulic pump motor 347 and the coolant pump motor 346. The cycle control lever 348 is then rocked in a counterclockwise direction to close the cycle start switch 354 so as to energize relay switch CR1 and to render the cycle control mechanism operative.

A selector switch 380 is provided for rendering the electric timer 376 operative or inoperative. When the selector switch 380 is positioned as shown in Fig. 13, the electric counter 376 is operative to control the grinding cycle. As shown in Fig. 12 the parts have been illustrated when the machine is idle and the fluid pressure pump 215 is stopped. Similarly the parts shown in the electric diagram (Fig. 13) are shown with the power turned off.

When it is desired to start a grinding cycle, the main control lever 365 is raised against the compression of the spring 368 to raise the stud 365a out of the path of the cam on the table stop dog 373 after which the lever 365 is moved toward the right to close the limit switch LS7 so as to energize the solenoid S2. Energizing the solenoid S2 serves to shift the valve member 292 into a right hand end position so that fluid under pressure is passed through the pipe 211, through the valve 197, through the pipe 193 into the cylinder chamber 194 to start the table 11 moving toward the right. As the table 11 moves toward the right, a table dog 373 moves off the plunger 369 thereby releasing the compression of the spring 371 so that the plunger 369 moves upwardly to actuate the limit switches LS1 and LS9. The normally closed contacts of the limit switch LS9 open to deenergize the solenoid S1. The normally open contacts of the limit switch LS9 close and energize the relay switch CR3. Energizing relay CR3 serves to energize the solenoid S4 to exhaust fluid from the cylinder chamber 255 through the valve 240 thus allowing the plunger 252 to move upwardly into the path of the next table dog 248.

Before the first dog 248 engages the arrow point 250 of the plunger 249, the dog 335 actuates the limit switch LS10 momentarily to energize the solenoid S9 to with-

draw the plungers 175 and 175a to inoperative positions. As soon as the solenoid S9 deenergizes fluid under pressure is passed from the valve 326 into the cylinder chambers 169 and 169a to swivel the wheel slide bases 128 and 128a in a counter-clockwise direction to position the grinding wheels 114 and 114a in a position for grinding the desired taper on the first cams on the cam shafts 54 and 39 respectively.

The table 11 continues its movement toward the right until the dog 248 engages the arrow point 250 and causes a downward movement of the plunger 249 to open the limit switch LS3 and to close the limit switch LS6. The closing of the limit switch LS6 serves also to energize the solenoid S7 to shift the control valve 291 so that the fluid exhausting from the table cylinder 190 will pass through the throttle valve 306 to slow down the longitudinal movement of the table. The table 11 continues moving at a slow down-rate of speed until the index dog 248 moves into engagement with the plunger 252 to stop the table in an indexed position. The closing of the limit switch LS6 also serves to energize the solenoid S3 to pass fluid under pressure from the valve 260 to the rock bar cylinder 75 to cause the rock bar to move to an operative position and also to pass fluid under pressure through the control valve 261 to the feed cylinders 150 and 150a to start an infeeding movement of the grinding wheels 114 and 114a.

When fluid under pressure is admitted to the cylinder chamber 91 to move the rock bar 25 to an operative position for a grinding operation, movement of the arm 375 in a counter-clockwise direction (Fig. 12) serves to open the normally open limit switch LS4 and to close the normally closed limit switch LS8. The closing of the limit switch LS8 serves to render the electric counter 376 operative for a grinding cycle. The closing of the limit switch LS8 serves also to energize a relay switch CR2 which closes a circuit to energize a relay switch MH automatically to start rotation of the work drive motor 61. When the selector switch 380 is in an off position, the work motor 61 may be manually controlled by actuation of the start switch 356.

During movement of the pistons 151 and 151a toward the right, fluid within the cylinder chambers 156 and 156a exhausts through the pipe 157, through the pipe 276, through the valve 261, through the pipe 283 and through the throttle valve 281 which may be regulated to control the rate of the infeeding movement of the grinding wheel. During the initial rapid feeding movement of the grinding wheels, the backlash in the feed mechanism parts is taken up by allowing a predetermined amount of fluid to momentarily exhaust through the backlash valve 274. The amount of fluid exhausting through the backlash valve 274 may be controlled by the throttle valve 272 which serves to control the rate of movement of the valve 274.

During the cam grinding operation, the rock bar 25 is rocked by rotation of the master cams 67 in engagement with the follower roller 68. During each oscillation of the rock bar 20, the limit switch LS5 is actuated by an arm 375 to impart an impulse to an electric counter 376. When the counter 376 is rendered operative by the closing of limit switch LS6, the contacts LC1 and RC1 are closed. After a predetermined number of impulses, that is, actuation of the limit switch LS5 by oscillation of the rock bar 25 during a grinding operation, the counter counts out and opens the contacts RC1 and LC1. At the start of the counting, the limit switch LS3 is opened and the contacts LC1 and RC1 of the counter 376 are closed, so that the solenoid S4 is energized even though the limit switch LS3 is opened by movement of the table dog 248 causing a downward movement of the plunger 249. When the counter 376 counts out, the forward advancing of the grinding wheels is stopped and a rearward movement of the wheel slides 110 and 110a is initiated. At count-out of the counter 376, contacts LC1 open and solenoid

S4 is deenergized which serves to shift the valve 310 so as to pass fluid under pressure through the pipe 243, through the valve 240, through the pipe 254 into cylinder chamber 255 so as to cause a downward movement of the piston 246 thereby causing a downward movement of the plunger 252 out of the path of the table index dog 248 so that the table 11 is free to move toward the right. The solenoid S1 is deenergized during the entire grinding cycle and is energized only prior to and during a grinding wheel truing operation so as to stop axial reciprocation of the grinding wheels. During the downward movement of the plunger 252, the limit switch LS6 is opened to deenergize the solenoid S3. The opening of the limit switch LS6 serves to deenergize relay switch CR4, thus opening a circuit to deenergize the solenoid S8. With the solenoid S8 deenergized, fluid under pressure from the reversing valve 300 passes through pipe 270 to shift the valve member 268 of the valve 261 into a left hand end position as shown in Fig. 12. With the valves 260 and 261 positioned as shown in Fig. 12, fluid under pressure from the fluid pump 215 passes through the pipe 218 through the pipe 264, through the valve 260, through the pipe 271, through ball check valve 282, through the valve 261, through the pipe 276 and the pipe 157 into the cylinder chambers 156 and 156a to cause the pistons 151 and 151a to move simultaneously toward the left to cause a rapid rearward movement of the grinding wheels 114 and 114a to inoperative positions. Fluid under pressure in the pipe 271 may also pass through the ball check valve 280 into the end chamber 273 of the backlash valve 274 to shift the valve toward the left into its initial position.

At the same time fluid under pressure is passed through the pipe 271 into the cylinder chamber 90 to move the piston 76 toward the right (Fig. 12) to rock the bar 25 to an inoperative position so as to facilitate a longitudinal indexing movement of the table 11. The rocking of the bar 25 to an inoperative position serves to rock the arm 375 in a clockwise direction into the position illustrated in Fig. 12 thereby closing the normally open limit switch LS4, opening the normally closed limit switch LS8 and opening the normally closed limit switch LS5. Opening the limit switch LS8 serves to deenergize the relay switch CR2 thereby breaking the circuit to deenergize the relay switch MH so as to break the circuit and thereby stop the work drive motor 61. Due to a holding circuit, the relay switch MH is deenergized, a circuit is maintained closed so that the motor 61 continues rotating the work until the cam 358 rotates through a partial rotation to open the normally closed limit switch LS2 thereby breaking a circuit to stop the motor 61 with the camshaft in predetermined positions.

When the counter 376 counts out at the end of a grinding cycle, opening the contacts LC1 serves to deenergize the solenoid S4 thereby shifting the valve 310 into the position illustrated in Fig. 12 so that fluid under pressure is passed through the pipe 243, through the valve 240, through the pipe 254 into the cylinder chamber 255 to move the piston 246 downwardly thereby withdrawing the plunger 252 out of the path of the table index dog 248. The closing of the limit switch LS4 by movement of the rock bar 25 to an inoperative position serves to energize the solenoid S2 so that fluid under pressure is passed through the pipe 211, through the valve 197, through the pipe 193 into the cylinder chamber 194 to move the cylinder 190 and the table 11 toward the right to index the next cams to be ground into an operative position relative to the grinding wheels 114 and 114a respectively. As the next table dog 248 moves toward the right, it engages the arrow point 250 and depresses the plunger 249 to slow down the movement of the table 11, in a manner above described, before the dog 248 engages the upper end of the plunger 252 to stop the table 11 in the next indexed position. The grinding

cycle of the next cam is repeated in a manner above described in connection with the grinding of the first cam on the cam shaft. This cycle of operation is repeated for each cam on the cam shaft to be ground. During each indexing movement of the table 11, the master cam follower roller 63 is indexed longitudinally into operative relation with the master cam 67 on the cam shaft 55.

After all of the cams have been ground as the table 11 is successively indexed toward the right, the table 11 moves a further distance toward the right beyond the last cam on the cam shafts being ground until the reversing dog 302 engages and actuates the reversing valve 300 to shift the valve into a reversing position so that the table 11 will move rapidly toward the left into an initial position.

During each table indexing movement toward the right, one of the dogs 336 or 337 actuates one of the limit switches LS12 or LS11 respectively so as to cause a swivelling movement of the wheel slides 110 and 110a to grind successive cams tapering in the opposite direction. As shown in the drawing, when the last cams on the left hand ends of the cam shaft 54 and 39 are ground, the limit switch LS12 is closed so that solenoid S6 is energized and fluid under pressure passes through the valve 325 through the pipe 171 to move the pistons 164 and 164a toward the right to swivel the wheel slide bases 128 and 128a in a clockwise direction.

On the return stroke of the table, that is, toward the left, the rapid speed continues until the stop dog 372 engages and actuates the plunger 369 (Fig. 12) which serves to actuate both the limit switches LS1 and LS9. At this time the solenoids S1 and S4 are both energized so that no fluid under pressure may pass through either the pipe 243 or the pipe 234. Downward movement of the plunger 369 opens the closed contacts of the limit switch LS1 to deenergize the solenoids S1 and S5. The closing of the open contacts of LS1 and LS9 serves to energize the relay switch CR3 to energize the solenoid S4 thereby allowing fluid to pass through the pipe 243, through the valve 240, through the pipe 254 to cause a downward movement of the piston 246 thereby withdrawing the plunger 252 out of the path of the truing dog 301. The downward movement of the plunger 252 serves to open the limit switch LS6 thereby deenergizing the solenoid S7 to shift the valve 291 into the position illustrated in Fig. 12 so that fluid exhausting from the cylinder chamber 194 passes through the valve 297, through the pipe 211, through the valve 290, through the pipe 209, through the valve 291 and through a pipe 390 and a throttle valve 391, through the throttle valve 306, through the ball check valve 307 and through the exhaust pipe 308 into the reservoir 217. By regulation of the throttle valve 391 the movement of the table 11 may be slowed to a very slow truing speed for a grinding wheel truing operation.

At the same time the truing dog 380 engages the plunger 249, the table stop dog 372 engages and depresses the plunger 369 depressing the plunger 369 shifts the limit switches LS1 and LS9 into the positions illustrated in Figs. 12 and 13. The closing of the lower contacts of limit switches LS1 and LS9 serves to energize the solenoid S1 and S5. Energizing the solenoid S1 serves to pass fluid under pressure through the pipe 234 into the cylinder chambers 235 and 235a to stop the grinding wheel spindle reciprocation. Fluid under pressure passes simultaneously through the pipe 308 into the cylinder chambers 180 and 180a to cause the stop plungers 175 and 175a to move downwardly into the position illustrated in Fig. 12. Energizing of the solenoid S5 serves to pass fluid under pressure through the pipe 331, through the valve 326 and through the pipe 168 into cylinder chambers 169 and 169a to cause the pistons 164 and 164a to swivel the wheel slide bases 128 and 128a in a counterclockwise direction so that the stop surfaces

176 and 176a engage the stop plunger 175 and 175a respectively so as to position the grinding wheels in a truing position.

The table 11 continues its travel toward the left at a truing speed while the plungers 249 and 369 ride on the bottom surfaces of the dogs 400 and 372 respectively while the truing tools 159 and 159a pass across the peripheral faces of the grinding wheels 114 and 114a to true the same. At the time the reversing dog 302 shifts the reversing valve 300 at the right hand end of the table stroke, fluid under pressure is passed into the wheel feed compensators 224 and 224a to impart a compensating feed to the wheel slides 110 and 110a. This movement advances the grinding wheels by a predetermined amount for the truing operation. The truing movement of the table 11 toward the left continues until reversing dog 303 engages and actuates the reversing valve 300 to shift the flow of fluid to the table cylinder so as to start the table 11 moving in the reverse direction. At the same time fluid under pressure is passed through the pipe 227 to impart a second compensating feed to the grinding wheel slides 110 and 110a before the truing tools 159 and 159a move into engagement with the grinding wheels 114 and 114a for a second pass of the truing tools across the peripheral faces of the wheels. This movement of the table 11 toward the right continues until the dog 373 engages the lug 365a and rotates the lever 365 in a clockwise direction so as to open the limit switch LS7 and thereby stops the table 11 in a loading position while the ground work pieces are removed and new pieces of work to be ground are inserted there instead.

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.

I claim:

1. In a camshaft grinding machine having a base, a plurality of spaced transversely movable wheel slides thereon, a rotatable grinding wheel on each of said slides, a longitudinally movable table on said base, a rock bar pivotally mounted on said table, the pivotal axis of the rock bar being parallel to the axis of said grinding wheels, a plurality of spaced axially aligned headstocks and footstocks on said rock bar simultaneously to support a plurality of camshafts to be ground, a rotatable spindle on each of said headstocks, means including a single motor on said table operatively connected synchronously to rotate all of said headstock spindles, means including a single set of spaced master cams mounted on one of said spindles, and a follower single roller successively engageable therewith and rotatably supported on said table to impart a rocking movement to said rock bar simultaneously to grind corresponding cams on each of the camshafts to be ground.

2. In a camshaft grinding machine having a base, a pair of spaced transversely movable wheel slides thereon, a rotatable grinding wheel on each of said slides, a longitudinally movable table on said base, a rock bar pivotally mounted on said table, the pivotal axis of the rock bar being parallel to the axis of said grinding wheels, a pair of spaced axially aligned headstocks and footstocks on said rock bar simultaneously to support a pair of camshafts each having a plurality of spaced cams to be ground in axial alignment with each other, a rotatable spindle on each of said headstocks, means including a single motor on said table operatively connected synchronously to rotate both of said headstock spindles, means including a single set of spaced master cams on one of said spindles, and a follower roller engageable therewith and rotatably supported on said table to impart a rocking movement to

said rock bar simultaneously to grind corresponding cams on each of the camshafts to be ground.

3. In a camshaft grinding machine having a base, a pair of spaced transversely movable wheel slides thereon, a rotatable grinding wheel on each of said slides, a longitudinally movable table on said base, an independent feeding mechanism including an independent fluid motor for feeding each of said slides toward and from said table, means including a single control valve mechanism simultaneously to control said fluid motors so as to cause a simultaneous infeeding movement of both of the wheel slides, means including a fluid motor to index said table longitudinally, a rock bar pivotally mounted on said table, a pair of spaced axially aligned headstocks and footstocks on said rock bar simultaneously to support a pair of camshafts to be ground, a rotatable spindle on each of said headstocks, means including a single motor on said table synchronously to rotate both of said spindles, means including a single set of spaced master cams on one of said spindles, and a master cam follower roller successively engageable therewith and rotatably supported on said table to impart a rocking movement to said rock bar simultaneously to grind corresponding cams on each of the camshafts to be ground.

4. In a camshaft grinding machine as claimed in claim 1, in combination with the parts and features therein specified of a vertical pivot for each of said wheel slides to facilitate a swivelling movement of the slides in a horizontal plane, an independent fluid motor operatively connected to swivel each of said slides in either direction, and a single control valve mechanism actuated by and in timed relation with the table movement simultaneously to control all of said swivelling motors so as to simultaneously swivel each of the wheel slides in one direction to position the grinding wheels for grinding a predetermined taper in one direction on part of the corresponding cams on each of said camshafts and simultaneously to swivel said slides in the opposite direction simultaneously to grind a predetermined taper in the opposite direction on the remainder of the corresponding cams on each of said camshafts.

5. In a camshaft grinding machine, as claimed in claim 1, in combination with the parts and features therein specified of a vertical pivot for each of the wheel slides to facilitate a swivelling movement of the slides in a horizontal plane, an independent fluid motor operatively connected to swivel each of said slides in either direction, and a single control valve mechanism actuated by and in timed relation with the table movement simultaneously to control all of the fluid motors so as to alternately and simultaneously swivel said slides in the opposite directions after each cam has been ground to facilitate grinding a predetermined taper in opposite directions on corresponding alternate cams on each of said camshafts to be ground.

6. In a camshaft grinding machine, as claimed in claim

1, in combination with the parts and features therein specified of an independent wheel spindle reciprocating mechanism for each of the grinding wheel slides, means including an independent piston and cylinder to render each of said reciprocating mechanisms inoperative, and means including a single control valve mechanism simultaneously to control the admission to and exhaust of fluid from said cylinders so as to simultaneously stop reciprocation of both of the wheel spindles during a grinding wheel truing operation.

7. In a camshaft grinding machine, as claimed in claim 1, in combination with the parts and features therein specified in which the wheel feeding mechanism comprises a manually operable nut and screw mechanism, an independent wheel feed compensator for each of said feeding mechanism which are arranged to actuate said nut and screw mechanism to advance each of the grinding wheels prior to a truing operation, and means including a single control valve mechanism to control the admission to and exhaust of fluid from the feed compensators so as simultaneously to advance all of the wheel slides by a predetermined amount before each pass of the truing tool across the face of the grinding wheel.

8. In a camshaft grinding machine, as claimed in claim 1, in combination with the parts and features therein specified of an independent locating plunger for locating each of the wheel slides in a central position for a grinding wheel truing operation, an independent piston and cylinder for actuating each of said plungers, and means including a single control valve mechanism to control the admission to and exhaust of fluid from said cylinders automatically and simultaneously to move the plungers into an operative position before a truing operation.

9. In a camshaft grinding machine, as claimed in claim 1, in combination with the parts and features therein specified of an independent piston and cylinder for swivelling each of the wheel slides in opposite directions precisely to position the grinding wheels for grinding opposite tapers on the cams being ground, means including an independent locating plunger for locating each of the wheel slides in a central position for a grinding wheel truing operation, an independent piston and cylinder for actuating each of said plungers, and means including a single control valve for simultaneously controlling the admission to and exhaust of fluid from the swivelling and plunger actuating cylinders.

References Cited in the file of this patent

UNITED STATES PATENTS

1,254,253	Marchant	Jan. 22, 1918
2,535,130	Green et al.	Dec. 26, 1950
2,581,759	Green	Jan. 8, 1952
2,641,089	Fouquet	June 9, 1953