Sept. 7, 1937. H. S. INDGE ET AL 2,092,734

CAM LAPPING MACHINE

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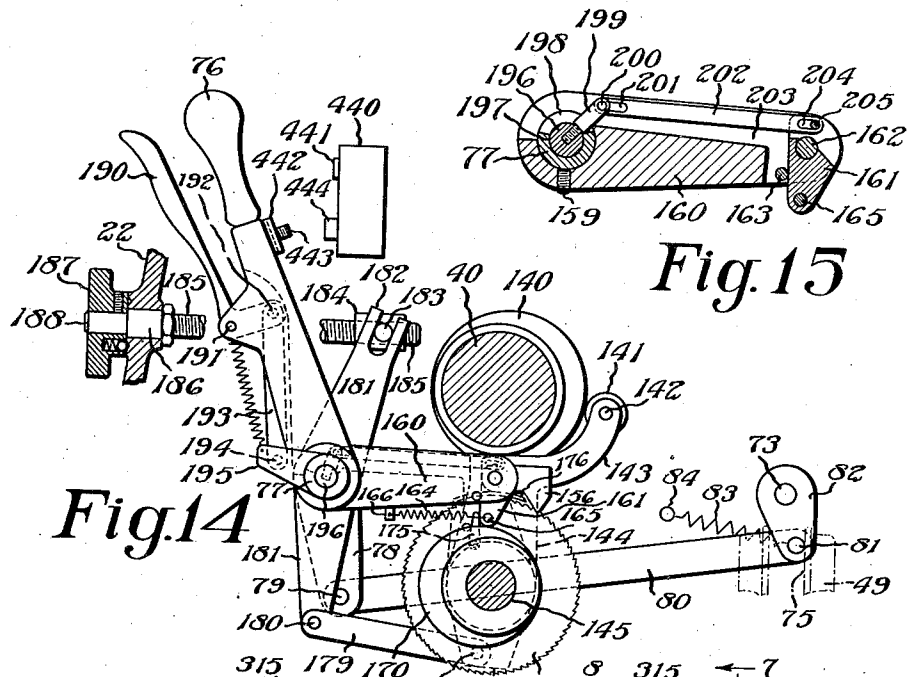


Fig. 15

Fig. 14

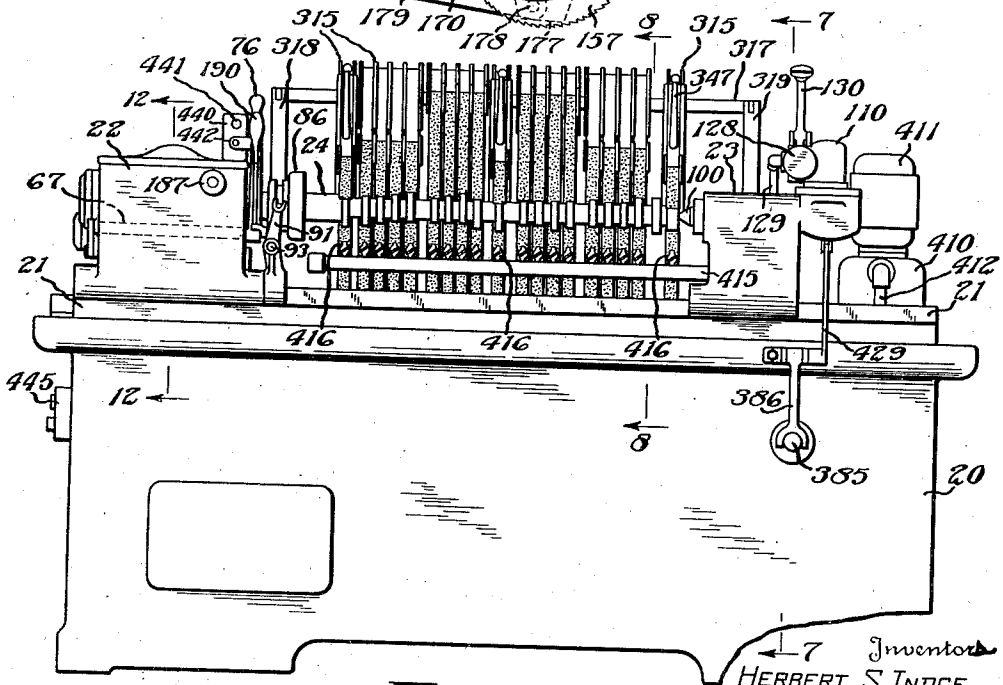


Fig. 1

Inventors
HERBERT S. INDGE
GEORGE E. HULBERT

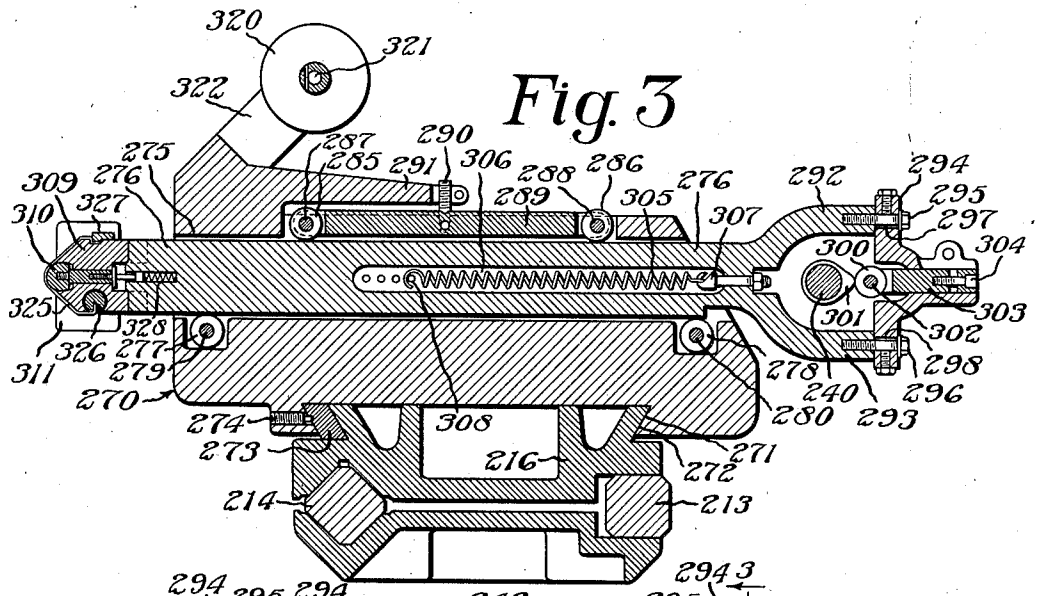
By Harold W. Eaton
Attorney

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CAM LAPPING MACHINE

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Fig. 3



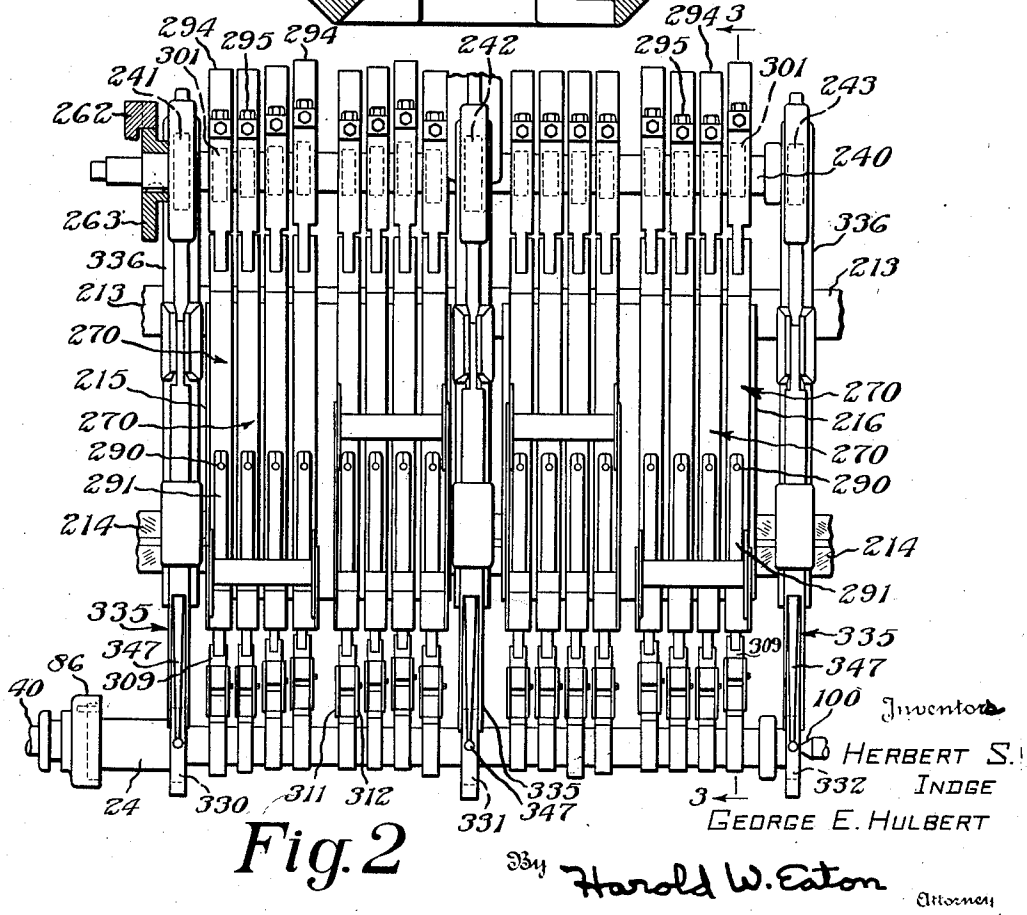


Fig. 2

Inventors
HERBERT S. INDGE
GEORGE E. HULBERT
By Harold W. Eaton
Attorney

Sept. 7, 1937. H. S. INDGE ET AL 2,092,734

CAM LAPPING MACHINE

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Fig. 4

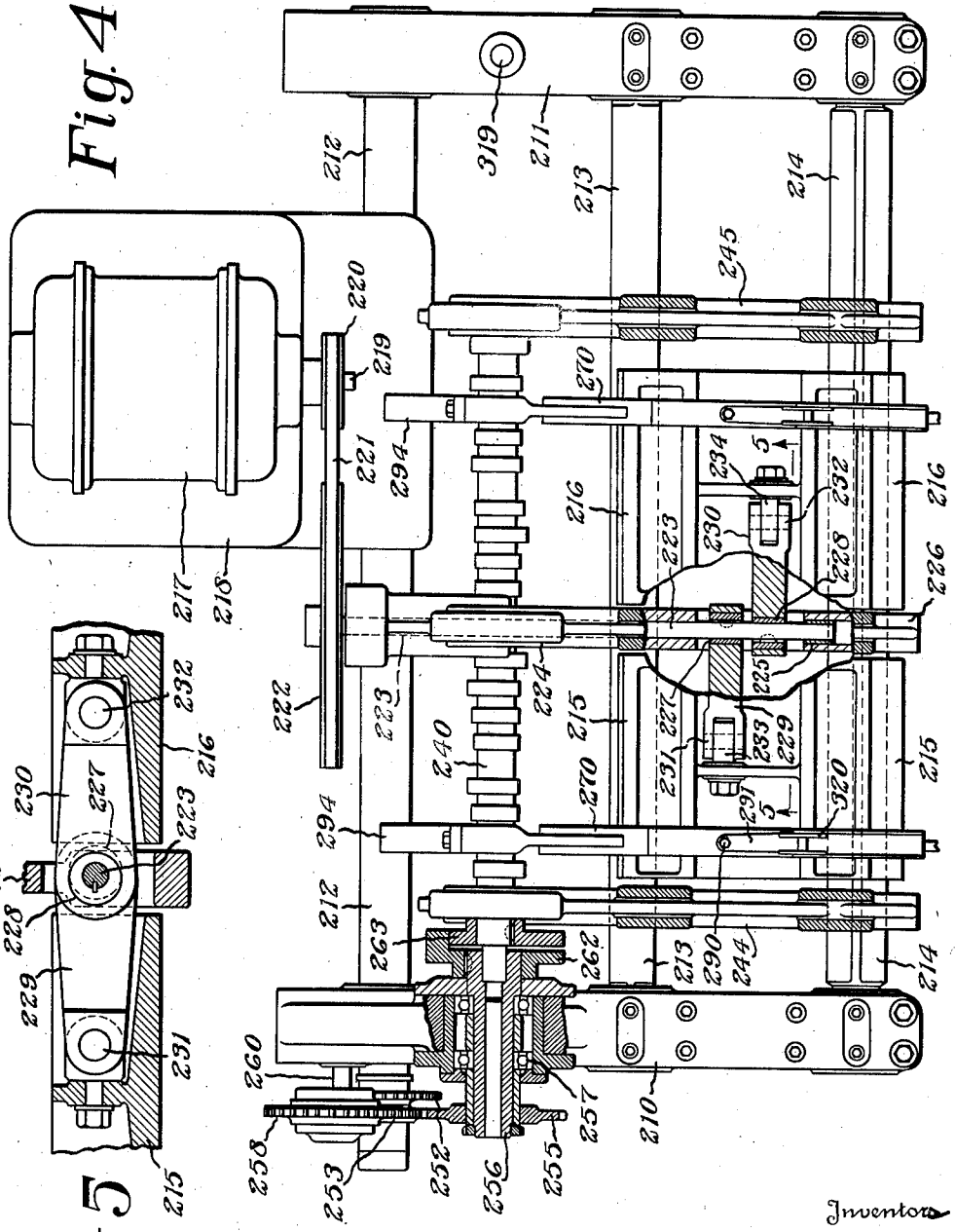


Fig. 5

Inventors
HERBERT S. INDGE
GEORGE E. HULBERT

By Harold W. Eaton
Attorney

Sept. 7, 1937. H. S. INDGE ET AL 2,092,734

CAM LAPPING MACHINE

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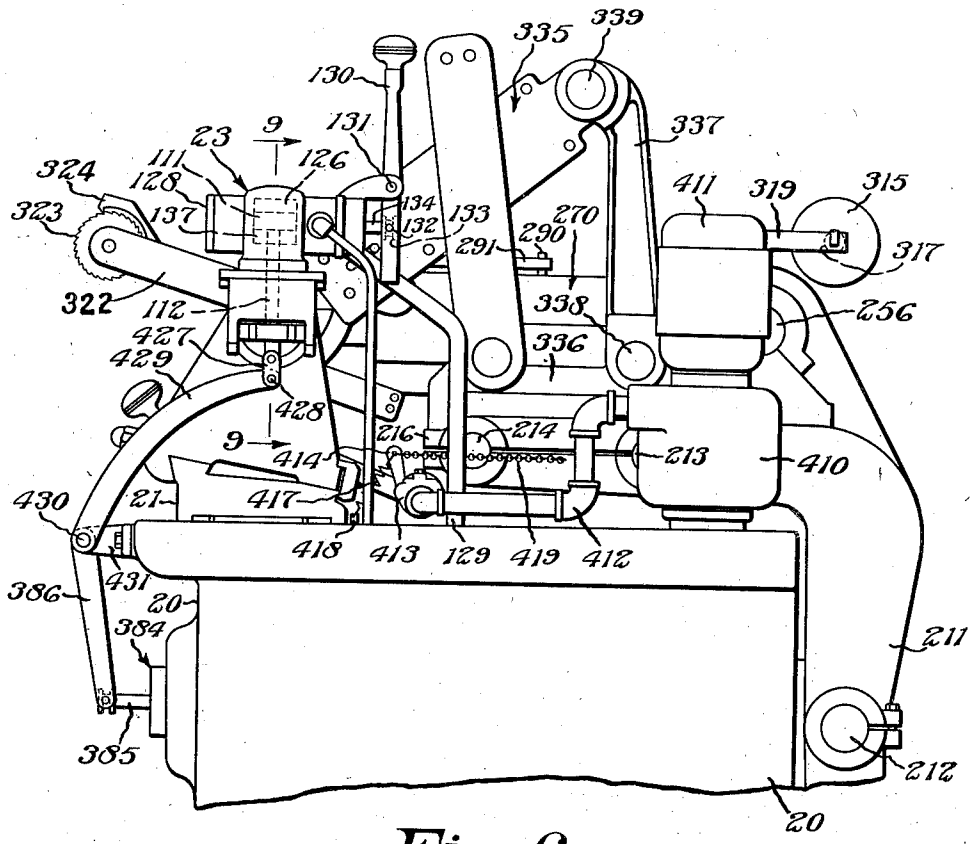


Fig. 6

Inventors
HERBERT S. INDGE
GEORGE E. HULBERT

By Harold W. Eaton
Attorney

Sept. 7, 1937. H. S. INDGE ET AL 2,092,734

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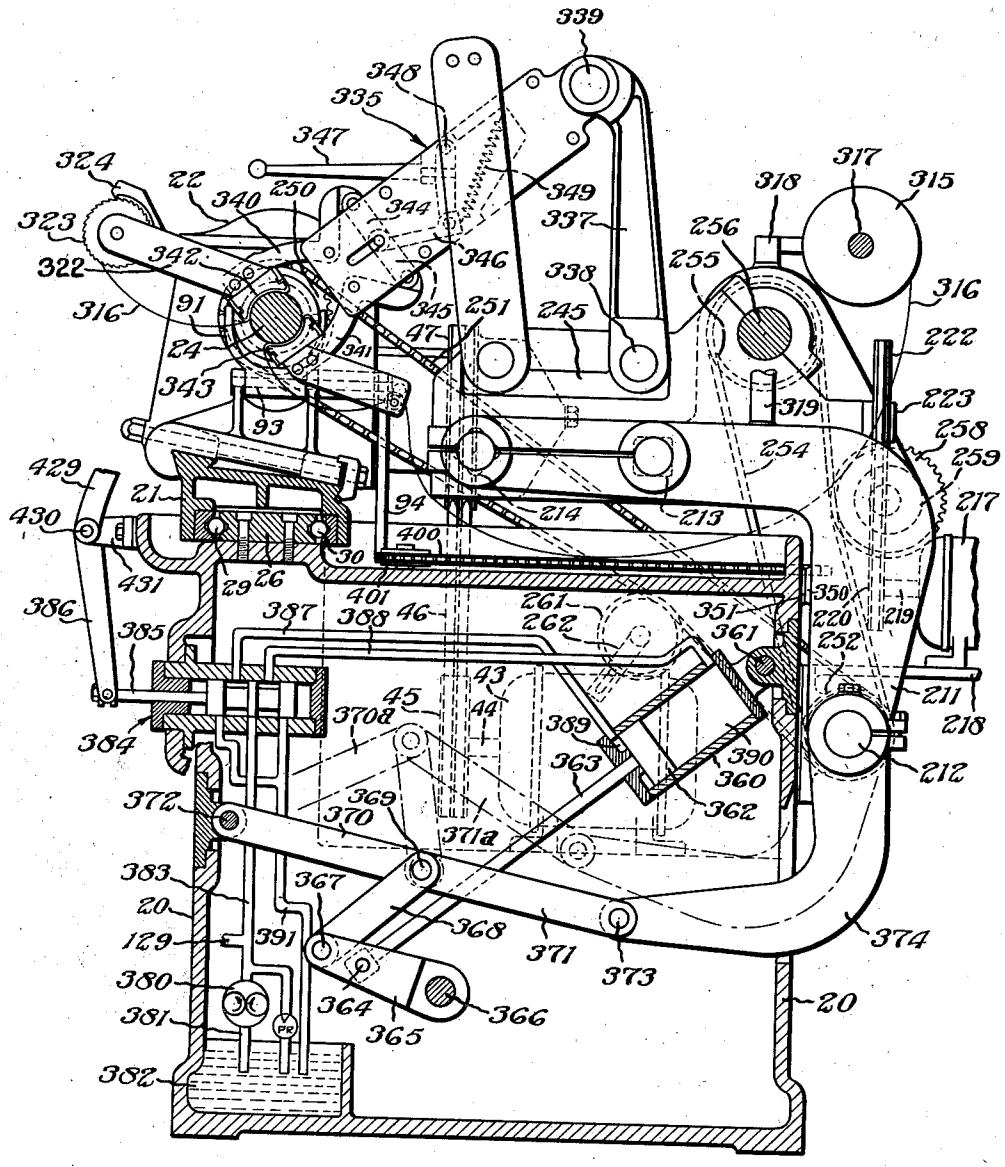


Fig. 7

Inventors
HERBERT S. INDGE
GEORGE E. HULBERT

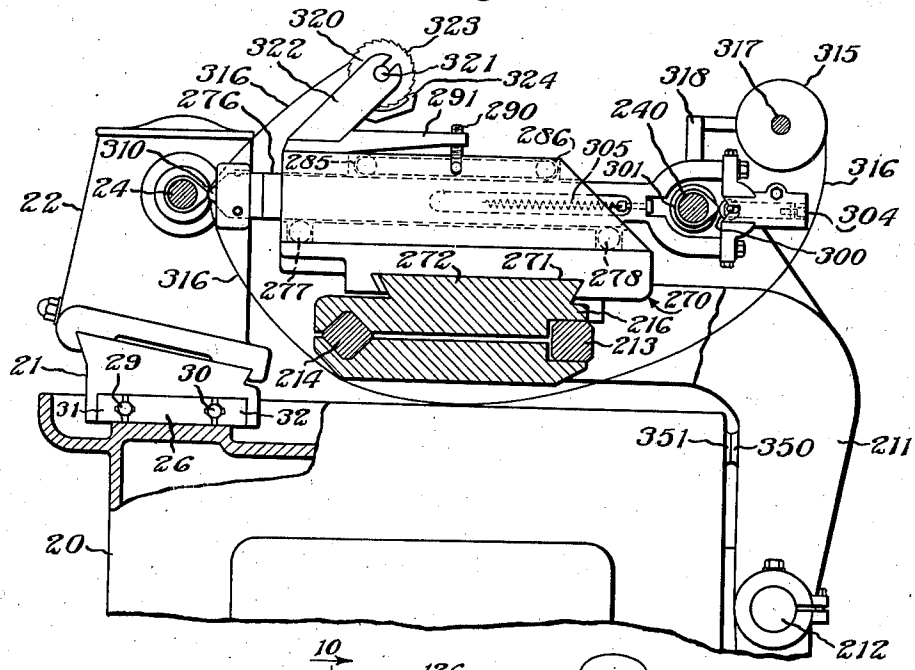
By Harold W. Eaton
Attorney

Sept. 7, 1937. H. S. INDGE ET AL 2,092,734

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Fig. 8



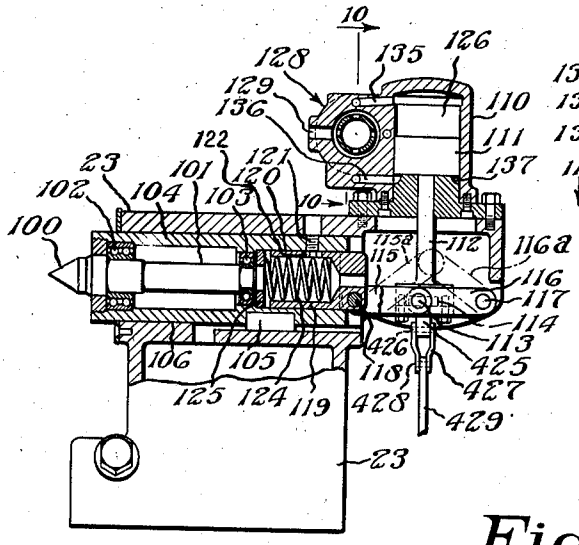


Fig. 9

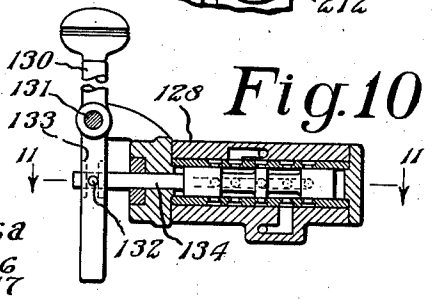


Fig. 10

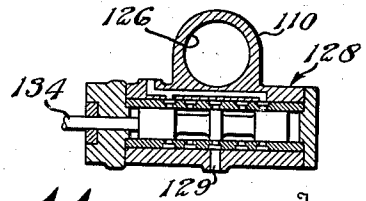


Fig. 11

Inventor
HERBERT S. INDGE
GEORGE E. HULBERT

By Harold W. Eaton
Attorney

Sept. 7, 1937. H. S. INDGE ET AL 2,092,734

CAM LAPPING MACHINE

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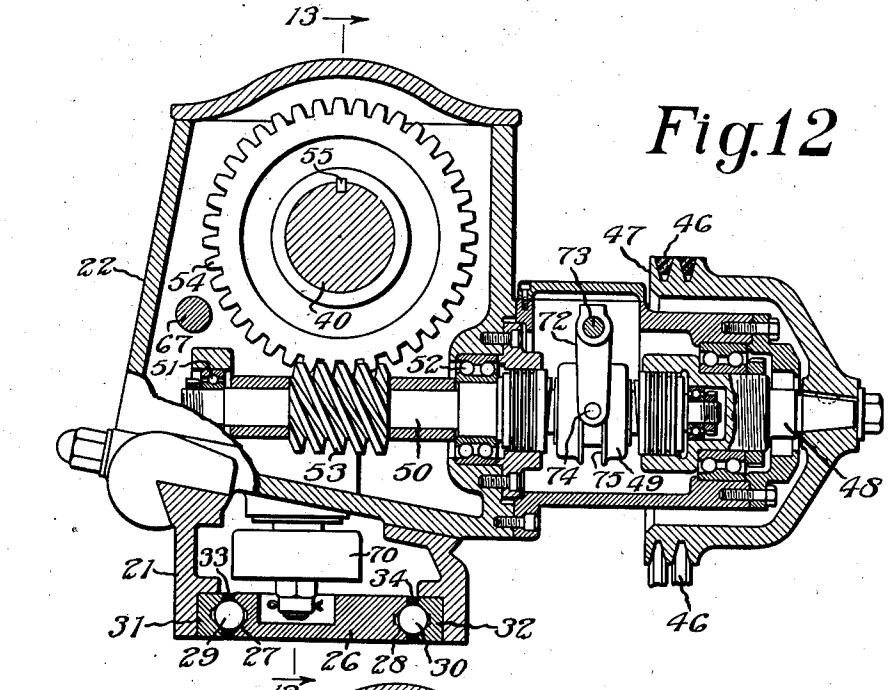


Fig.12

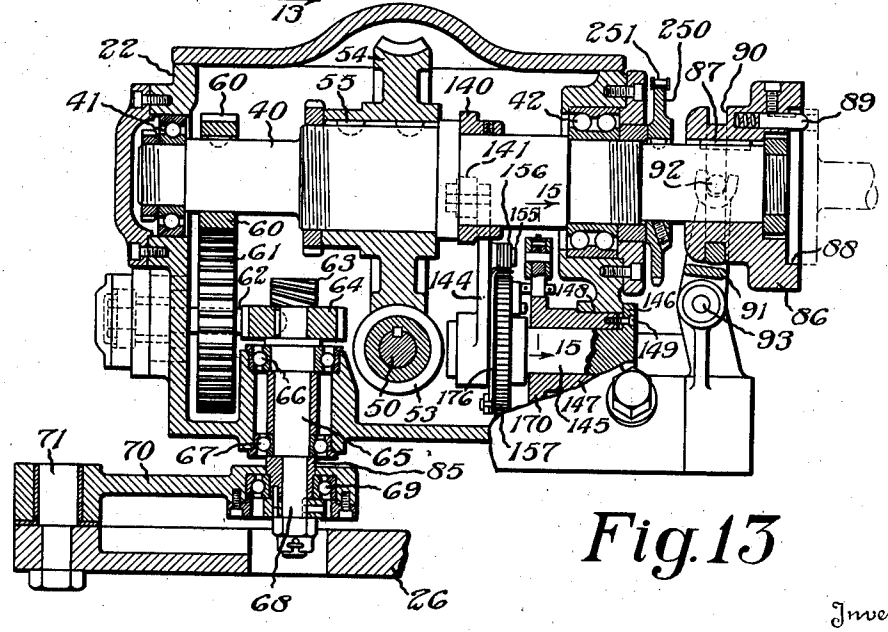


Fig.13

Inventors

HERBERT S. INDGE

GEORGE E. HULBERT

By Harold W. Eaton

Attorney

Patented Sept. 7, 1937 2,092,734

UNITED STATES PATENT OFFICE

2,092,734

CAM LAPPING MACHINE

Herbert S. Indge and George E. Hulbert, Westboro, Mass., assignors to Norton Company, Worcester, Mass., a corporation of Massachusetts

Application August 21, 1936, Serial No. 97,232

21 Claims. (Cl. 51—64)

This invention relates to abrading machines, and more particularly to a camshaft lapping machine.

One object of this invention is to provide a simple and thoroughly practical lapping machine for simultaneously lapping or polishing a plurality of cams on a camshaft. A further object of this invention is to provide a camshaft lapping machine in which all of the cams and bearing surfaces on a camshaft may be simultaneously lapped. Another object of this invention is to provide a lapping machine for simultaneously lapping the cams on a camshaft in which a plurality of lapping arms are provided, each being controlled by a master camshaft. A further object of the invention is to provide a camshaft lapping machine for simultaneously lapping all of the cams on a camshaft, in which a time control mechanism is provided to stop the lapping operation after the camshaft has been rotated a predetermined number of rotations.

A further object of the invention is to provide a plurality of bearing and cam lapping arms on a pivotally mounted support which may be swung to and from an operating position. A further object of the invention is to provide a fluid pressure control mechanism for simultaneously moving all of the cams and bearing lapping arms to and from an operating position. 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 various possible embodiments of the mechanical features of this invention,

Fig. 1 is a front elevation of the improved camshaft lapping machine;

Fig. 2 is a fragmentary plan view, on an enlarged scale, of the assembled cam and bearing lapping arms, showing the camshaft to be lapped and the master camshaft;

Fig. 3 is a cross-sectional view, on an enlarged scale, taken approximately on the line 3—3 of Fig. 2;

Fig. 4 is a fragmentary plan view of the machine, showing the reciprocating mechanism for the cam lapping arms;

Fig. 5 is a fragmentary sectional view, on an enlarged scale, taken approximately on the line 5—5 of Fig. 4, of the reciprocating mechanism for the cam lapping arms;

Fig. 6 is a fragmentary end elevation of the improved camshaft lapping machine;

Fig. 7 is a cross-sectional view, on an enlarged scale, taken approximately on the line 7—7 of Fig. 1, with the footstock removed and the end bearing lapping arm and its supporting parts shown in elevation, together with the actuating mechanism for moving all of the lapping arms to and from an operating position;

Fig. 8 is a fragmentary sectional view, on an enlarged scale, taken approximately on the line 8—8 of Fig. 1, showing a cam lapping arm in elevation;

Fig. 9 is a sectional view through the footstock, on an enlarged scale, taken approximately on the line 9—9 of Fig. 6;

Fig. 10 is a cross-sectional view through the footstock control valve, taken approximately on the line 10—10 of Fig. 9;

Fig. 11 is a longitudinal sectional view, taken approximately on the line 11—11 of Fig. 10;

Fig. 12 is a fragmentary cross-sectional view, on an enlarged scale, taken approximately on the line 12—12 of Fig. 1;

Fig. 13 is a fragmentary longitudinal sectional view, taken approximately on the line 13—13 of Fig. 12;

Fig. 14 is a fragmentary phantom view of the cycle timing mechanism; and

Fig. 15 is a fragmentary sectional view, taken approximately on the line 15—15 of Fig. 13.

A camshaft lapping machine has been illustrated in the drawings comprising a base 20 which supports a longitudinally reciprocable work supporting table 21. The table 21 in turn supports a headstock 22 and a footstock 23 which are arranged to rotatably support a camshaft 24 for a lapping operation.

Table ways are provided between the base 20 and the table 21 which in the preferred form are of an anti-friction type. The base 20 is provided with a plate 26 which is fixed to the base and is provided at its edge portion with grooves 27 and 28 which serves as an inner raceway for a pair of spaced rows of anti-friction balls 29 and 30. The table 21 is provided with outer raceways 31 and 32 which are grooved to bear against the anti-friction balls 29 and 30, respectively. A cage 33 and 34 is provided between the races to space the balls longitudinally, as desired. This construction forms an anti-friction way whereby the table 21, together with the headstock 22 and the footstock 23 may be readily reciprocated during the lapping operation.

Headstock

The headstock 22 is provided with a rotatable spindle 40 which is supported in anti-friction bearings 41 and 42 in the headstock casing. The headstock spindle 40 may be rotated from any suitable source of power, such as an overhead belt drive or a self-contained electric motor. In the preferred construction, an electric motor 43 is mounted on the base of the machine. A motor shaft 44 is provided with a driving pulley 45 which is connected by driving belts 46 with a pulley 47 which is mounted on the outer end of a transverse shaft 48 which is fixed to the headstock 22. A clutch 49 serves to connect the shaft 48 with a drive shaft 50 which is journaled in bearings 51 and 52 in the headstock 22. The shaft 50 carries a worm 53 which meshes with a worm gear 54 which is mounted on the spindle 40 and is locked thereto by means of a key 55.

When the movable clutch member 49 is moved toward the left (Fig. 12), the shaft 48 is connected through the clutch member 49 to rotate the shaft 50, the worm 53 and worm gear 54, transmitting a rotary motion to the headstock spindle 40. When the clutch member 49 is moved toward the right, it serves to disconnect the power driven shaft 48 and to brake the rotation of the shaft 50 so as quickly to stop the rotation of the spindle 40 and the camshaft 24.

Table reciprocation

In the lapping of a camshaft or other similar work piece, it is desirable to provide a relative reciprocatory movement between the work piece and the abrading element to prevent the production of grain markings on the surface of the work piece. In the present case, the work table 21 is arranged for a longitudinal reciprocatory movement. This is preferably accomplished by a translation of the rotary motion of the headstock spindle 40 into a reciprocatory movement for the table 21. The spindle 40 is provided with a gear 60 which meshes with a gear 61 mounted on a rotatable shaft 62. The shaft 62 carries a spiral gear 63 meshing with a spiral gear 64 mounted on the upper end of a vertically arranged shaft 65. The shaft 65 is journaled in bearings 66 and 67 in the headstock casing 22. An eccentric 68 is formed on the lower end of the shaft 65. The eccentric 68 is connected through an anti-friction bearing 69 with one end of a connecting rod 70. In order to facilitate adjustment of the reciprocatory motion transmitted by the eccentric 68, an adjustable eccentric bushing 85 fits on the eccentric 68 and its outer periphery carries the bearing 69. By adjusting the eccentric bushing, the reciprocatory stroke produced by the eccentric pin 68 may be varied. The other end of the connecting rod 70 is connected by a stud 71 with the base 20. As illustrated, the stud 71 is mounted on the member 26 which is in turn rigidly fixed to the base 20. It will be readily apparent from the foregoing disclosure that when the spindle 40 is rotated to rotate the work piece or camshaft 24, the rotary motion of the spindle is transmitted through the gear 60, the gear 61, the shaft 62, the spiral gear 63, the spiral gear 64, to rotate the shaft 65 and the eccentric 68 which, through the anti-friction bearing 69 and the connecting rod 70, serves to cause a longitudinal reciprocatory movement of the table 21 so as to relatively reciprocate the work piece relative to the lapping members.

The clutch member 49 is arranged so that it may be readily shifted from a driving to a braking position. This is preferably accomplished by means of a yoked member 72 which is supported on a rock shaft 73. The yoked member 72 is provided with opposed pins 74 which ride within a groove 75.

A manually operable lever 76 is connected to one end of a shaft 77 which is journaled in the headstock 22. A downwardly extending lever 78 is connected on the outer end of the shaft 77 and is connected by a stud 79 with a link 80 which is connected by a stud or pin 81 carried by a downwardly extending lever 82 which is mounted on the rock shaft 73. When the lever is moved into the position (Fig. 14), the clutch member 49 is shifted into a driving position so as to connect the drive shaft 48 with the shaft 50 to cause a rotation of the headstock spindle 40 and the camshaft 24. The lever 76 may be moved in a clockwise direction (Fig. 14) to rock the arm 82 in a clockwise direction which serves to shift the clutch member 75 toward the left (Fig. 14) to disconnect the driving shaft 48 from the shaft 50 and thereby apply the brake to stop the rotation of the shaft 50 and also the headstock spindle 40 and the camshaft 24. A spring 83 connected between the stud 81 carried by the arm 82 and a stud 84 fixed on the headstock casing 22 exerts a tension tending to hold the clutch member 49 in a braking position.

Work support

The headstock spindle 40 serves as a rotatable support and driver for the camshaft 24 to be lapped. As illustrated in the drawings, a work driving member 86 is slidably keyed to the spindle 40 by means of a key 87. The member 86 is provided with a recess 88 which is arranged to receive the flanged end of a camshaft, the outer diameter of the recess 88 being of a size to receive the peripheral surface of the flanged end of a camshaft. The driving member 86 is provided with a spring-pressed driving pin 89 which engages a locating hole in the flange on the end of the camshaft 24 to locate the camshaft in a definite relation with the driving spindle and to serve as a driving means to positively rotate the camshaft with the headstock spindle 40. To facilitate loading of a work piece into the machine, the work driving member 86 is arranged so that it may be moved longitudinally on the spindle. The driving member 86 is provided with a peripheral groove 90 which is straddled by a yoked member 91 having opposed pins 92 which ride in the groove 90. The yoked member 91 is pivotally mounted on a stud 93 and is connected to a downwardly projecting actuating lever 94 by means of which the driving member 86 may be withdrawn to facilitate loading of a work piece into the machine.

Footstock

The other end of the camshaft 24 is supported by the footstock 23 which is provided with a footstock center 100 which is carried by a rotatable spindle 101. The spindle 101 is journaled in bearings 102 and 103 within a hollow slidably mounted sleeve 104. The sleeve 104 is slidably keyed by means of a key 105 within an aperture 106 in the footstock frame 23.

A fluid pressure actuating mechanism is provided to move the footstock center 100 rapidly to and from an operative position to support a camshaft within the machine. This mechanism comprises a fluid pressure cylinder 110 having a

slidably mounted piston 111 contained therein. The piston 111 is connected to one end of a piston rod 112, the other end of which is connected through a pin 113. The central portion of the pin 113 is slabbed off on opposite sides so as to slide within an elongated slot 114 formed at the lower end of the piston rod 112. The pin 113 serves as a central pivotal connection between a pair of toggle levers 115 and 116. The toggle lever 116 is connected to the footstock frame 23 by means of a stud 117. The end of the toggle lever 115 is connected by a stud 118 with a slidably mounted sleeve 119 which slides within an aperture 120 within the sleeve 104. The sleeve 119 is held against rotation by means of a pin 121 carried by the sleeve 104 which rides within an elongated slot 122 in the sleeve 119. A spring 124 is contained within the sleeve 119 and is interposed between the end of the sleeve 119 and a thrust collar 125.

When fluid under pressure is admitted to the cylinder chamber 126, toggle levers 115 and 116 are moved from the dotted line positions 115*a* and 116*a* into the full line positions 115 and 116 (Fig. 9) which serves to move the sleeve 119 into the position illustrated which in turn serves to compress the spring 124 and, through the connecting parts, move the sleeve 104 and footstock center 100 into operative supporting engagement with the end of the camshaft 24.

In order readily to control the movement of the footstock center, a control valve 128 is formed integral with the cylinder 110. The valve 128 is preferably of a piston type and serves to control the admission of fluid passing through the pipe 129 to the cylinder. A control lever 130 which is pivotally mounted on a stud 131 carried by the valve casing 128 is connected by a stud 132 with a spool shaped member 133 carried by a valve stem 134. The valve 128, as shown in Fig. 10, is in a neutral position. If the lever 130 is moved either clockwise or counterclockwise (Fig. 10), fluid is admitted either through a passage 135 into cylinder chamber 126 to cause the pistons 111 to move downwardly and the footstock center 100 to move into an operating position in engagement with the work, or may pass through a passage 136 into a cylinder chamber 137 to cause the piston 111 to move upwardly and to thereby withdraw the footstock center 100 from supporting engagement with the camshaft 24.

Time control mechanism

It is one of the objects of this invention to provide a suitable time control mechanism whereby a work piece, such as the camshaft 24, may be rotated for a predetermined time interval to produce the desired finish on the surface of the work piece. In the preferred construction, a counting mechanism is provided which serves automatically to stop the lapping operation after the work piece has rotated a predetermined number of rotations in engagement with the lapping elements. This mechanism is preferably contained within the headstock 22 and has been illustrated in Fig. 14. The headstock spindle 40 carries an eccentric 140 which is engaged by a roller 141 mounted on a stud 142. The stud 142 is carried by a lever 143 which has a downwardly extending projection 144 which is rotatably supported on a shaft 145. The shaft 145 is held in a fixed position relative to the headstock frame 22. The shaft 145 is provided with a flanged portion 146. A bushing 147 fits within an aperture 148 in the headstock frame 22 and a shoulder thereon engages an inner surface of the casing 22 of the headstock. A plurality of screws 149 serve to clamp the flange 146 rigidly to the bushing 147 and to hold both of said members in fixed relation with the headstock casing 22. The rock arm 143 and 144 carries a stud 155 which pivotally supports a plurality of pawls 156. The pawls 156 are arranged to engage a ratchet wheel 157 which is rotatably supported on the shaft 145. The pawls 156 are preferably four in number, each of which is of a slightly different effective length, the difference between said pawls being substantially equal to one-quarter of a tooth on said ratchet wheel 157, thus permitting a fine adjustment of the movement of the ratchet wheel 157 so that it may be moved by small increments of one-quarter of a tooth or by larger increments constituting one or more teeth of the ratchet at each actuation of the pawls 156.

In order to hold the clutch 49 in a driving position in engagement with the clutch member to connect the shaft 48 with the shaft 50, the shaft 77 is provided with an arm 160 which is fixed to the shaft 77 by means of a set screw 159, so that when the shaft 77 is rocked, the member 160 will be rocked thereby. The lever 160 carries a pivotally mounted detent 161 which is carried by a stud 162 on the arm 160. A stop pin 163 serves to limit the movement of the detent 161 in a clockwise direction, and a spring 164 interposed between a stud 165 on the detent 161 and a stud 166 on the arm 160 serves to normally hold the detent 161 in the position illustrated in Figs. 14 and 15.

An adjustably positioned eccentric 170 is formed integral with the bushing 147 and serves to engage and support the end of the detent 161 so as to hold the clutch member 49 in driving engagement with the drive shaft. The eccentric 170 may be adjusted by loosening the screws 149 (Fig. 13) and rotating the shaft 145 and the bushing 147 so that the detent 161 and arm 160 are adjusted so as to hold the clutch in driving engagement. The eccentric 170 may then be locked and requires no further adjustment during the operation of the machine. It should be noted that in the position of the parts (Fig. 14), the stud 165 and the effective portion of the detent 161 engage the eccentric 170 at a point slightly beyond a line or plane passing through the axis of the stud 162 and the axis of the shaft 145, so that the detent 161 is thereby held in position (Fig. 14) to lock the clutch 49 in a driving position. The clutch 49 remains in driving engagement with the work piece until a pivotally mounted detent 175 carried by the ratchet wheel 157 engages the stud 165 and rocks the detent 161 in a counterclockwise direction, thereby unlocking the parts, and the released tension of the spring 83 serves to rock the lever 76, the lever arm 160 and the clutch 49 to disengage the same and to apply the brake and thereby rapidly stop the rotation of the headstock spindle and the camshaft being lapped.

It is desirable to provide a readily accessible means to adjust the lapping period, that is the number of rotations of the camshaft or work piece while in engagement with the lapping element. This may be accomplished by providing an adjustable shield 176 which is pivotally mounted on the shaft 145 and has a downwardly extending projection 177 which is connected by a pin 178 with a link 179. The link 179 is connected

by a stud 180 with a rock arm 181 which is pivotally mounted on the shaft 77. The upper end of the rock arm 181 is formed as a yoked member 182 which straddles a pin 183 carried by a nut 184. The nut 184 meshes with or engages a correspondingly threaded screw 185 which is rotatably supported in a bearing 186 in the headstock casing 22. An adjusting knob 187 is mounted on the outer end 188 of the screw 185 projecting outside the headstock. By rotation of the adjusting knob 187, the position of the nut 184 may be adjusted lengthwise of the screw 185 which in turn serves to rock the arm 181 and, through the link 179, serves to rock the pawl shield 176 so as to vary the effective motion of the pawls 156 as desired. By adjusting the position of the shield 176 relative to the pawls 156, the extent of movement of the ratchet wheel 157 may be varied from one-quarter of one tooth to several teeth, as desired. By this adjustment, the lapping period may be adjusted so that the work piece or camshaft 24, to be lapped, may be rotated a predetermined number of turns and then automatically stopped. The greater the number of teeth of the ratchet wheel picked up at each actuation of the pawl 156, the shorter the lapping cycle and the lesser the number of teeth picked up at each actuation of the pawl 156, the longer the lapping cycle or period.

It is desirable to provide a manual means for stopping the lapping cycle at any time during the lapping operation, if desired. A manually operable bell crank lever 190 is pivotally mounted on a stud 191 carried by the control lever 76. The short arm of the bell crank lever 190 carries a pin 192 which is connected to the upper end of a link 193. The lower end of the link 193 is connected by a pin 194 with a rock arm 195 which is mounted on the outer end of a shaft 196. The shaft 196 is a relatively short shaft carried in an aperture 197 within the shaft 77. The upper surface of the shaft 77 is provided with a slot 198. A pin 199 passes through the slot 198 and is screw threaded into shaft 196. The pin 199 is provided with a stud 200 which rides within an elongated slot 201 in a link 202 supported within a slotted portion 203 of the lever 160. The other end of the link 202 is provided with an elongated slot 204 which is connected by a pin 205 with the upper end of the detent 161. By rocking the bell crank lever 190 in a clockwise direction toward the lever 76, the detent 161 may be rocked in a counterclockwise direction so as to unlock the lever 160 and allow the released tension of the spring 83 to disengage the driving clutch and to brake the rotation of the shaft 50, thus providing a readily accessible means for stopping the lapping operation at any time during the cycle, if desired.

Lapping arm support

It is desirable to provide a movable support for a plurality of lapping arms so that they may be simultaneously and quickly moved into an operating or an inoperative position, as desired. A pair of spaced supporting arms 210 and 211 are mounted on a rock shaft 212 which is supported in bearings on the rear of the machine base. The arms 210 and 211 are connected by two spaced bars 213 and 214 which serve as slide bars or ways for a pair of spaced slides 215 and 216, each of which is arranged to support a plurality of cam lapping arms to be hereinafter described.

It is desirable to reciprocate the cam lapping arms at a rapid rate to cause a relative longitudinal movement between the lapping arms and the cam being lapped. If a heavy mass is reciprocated rapidly, the rapid movement and reversal sets up vibrations within the machine which detrimentally affect the lapping operation. In order to overcome this difficulty and to reduce vibration to a minimum, it is desirable to divide the lapping arms into two or more sets, each set of which is mounted on a separate slide, and to reciprocate the slides simultaneously in opposite directions so that the tendency to set up vibrations within the parts is reduced to a minimum. As illustrated in the drawings, two slides 215 and 216 have been provided, each slide being arranged to support half of the lapping arms.

Cam lapping and reciprocating mechanism

A motor driven reciprocating mechanism has been provided for reciprocating the slides 215 and 216 so as simultaneously to reciprocate the two sets of lapping arms in opposite directions. An electric motor 217 is mounted on a projecting shelf 218 which is carried by the rock shaft 212. The motor 217 is provided with a drive shaft 219 having a driving pulley 220 which is connected by a driving belt 221 with a pulley 222 which is mounted on the outer end of a transversely mounted rotatable shaft 223. The shaft 223 is journaled in bearings 224 and 225 in a frame 226 carried by the guide bars 213 and 214. The shaft 223 carries two eccentrics 227 and 228 which are arranged with their throws in diametrically opposite positions. The eccentrics 227 and 228 are connected by connecting rods 229 and 230 with studs 231 and 232 respectively which are supported in brackets 233 and 234 carried by the slides 215 and 216 respectively. When the motor 217 is set in motion, a rotary motion is transmitted through the pulley 220, the pulley 222, the shaft 223, the eccentrics 227 and 228 the connecting rods 229 and 230, to simultaneously reciprocate the slides 215 and 216 in opposite directions.

Master camshaft

In order that the cam lapping arms to be hereinafter described may be maintained in uniform lapping engagement with the cams on the camshaft, a master camshaft 240 is rotatably journaled in bearings 241, 242 and 243 which are carried by the bracket 226 and a bracket 244 and 245 carried by the guide rods 213 and 214. The master camshaft 240 is identical with the shaft 24 to be lapped.

It is desirable to provide a suitable driving mechanism for the master camshaft 240, whereby the rotation of the master shaft 240 and the shaft 24 to be lapped may be synchronized. In the preferred form, the rotary motion of the headstock spindle 40 is transmitted through a driving mechanism to rotate the master camshaft 240 in synchronism therewith. A sprocket 250 is mounted on the headstock spindle 40 and is connected by a link chain 251 with a sprocket 252 rotatably supported on the rock shaft 212. A second sprocket 253 is rotatably mounted on the rock shaft 212 and is connected by a link chain 254 with a sprocket 255 mounted on a driven shaft 256 which is journaled in bearings 257 in the supporting arm 210. An adjustably positioned idler sprocket 258 is rotatably supported on an eccentric 259 carried by a shaft 260 mounted on the arm 210. By adjusting the eccentric relative to the sprocket 258, the tension

of the driving chain 254 may be varied, as desired. An idler sprocket 261 is rotatably supported on an adjustable bracket 262 and serves to tension the link chain 251.

The shaft 256 carries a driving plate 262 which is connected through a plate 263 which is keyed to the end of the master camshaft 240. It will readily be apparent from the foregoing disclosure that when the headstock spindle 40 is rotated, a rotary motion will be transmitted through the sprocket 250, link chain 251, sprocket 252, sprocket 253, link chain 254, sprocket 255, to rotate the shaft 256, and through the connections 262—263 to rotate the master camshaft 240 in synchronism with the rotation of the camshaft to be lapped.

In order that all of the cams on the camshaft may be simultaneously lapped, a plurality of cam lapping arms 270 are mounted on each of the longitudinally movable slides 215 and 216. The cam lapping arms 270 are positioned and arranged so that an abrading end thereof operatively and simultaneously engages each of the cams on said camshaft 24 to be lapped. Only one of the cam lapping arms has been shown in detail, as illustrated in Figs. 3 and 8, but the entire assembly and arrangement thereof has been illustrated in Fig. 2. The lapping arms 270 are provided with a hollow frame which is provided on its lower surface with a dovetailed way 271 which mates with a correspondingly shaped way 272 on the slide 215 or 216. A gib 273 together with an adjusting screw 274 serves to facilitate adjustment of the arm 270 longitudinally on the slides 215 and 216 to position the cam lapping arms in the desired relationship with the cams to be lapped.

Each of the lapping arms 270 is provided with a longitudinally extending aperture 275 which is adapted to receive a slide 276. The slide 276 is supported on its lower surface on a pair of spaced rollers 277 and 278 which are rotatably supported on studs 279 and 280 respectively, thus furnishing an anti-friction support for the transversely movable slide 276. In order to maintain the slide 276 in operative contact with the supporting rollers 277 and 278, a pair of rollers 285 and 286 are supported on studs 287 and 288 which are in turn carried by an adjustable member 289. The member 289 may be adjusted in a vertical direction by means of an adjusting screw 290 carried by a projection 291 of the arm 270. By adjusting the screw 290 vertically, the rollers 285 and 286 may be adjusted relatively toward or from the rollers 277 and 278 so as to take up any play or lost motion between the slide 276 and the arm 270.

The rear end of the slide 276 is formed as a yoked end having arms 292 and 293 which straddle the master camshaft 240. An end cap 294 is adjustably mounted on the ends of the arms 292 and 293 by means of clamping screws 295 and 296 which pass through elongated slots 297 and 298 in the end cap 294 and are screw threaded into the arms 292 and 293. The end cap 294 supports a master cam follower roller 300 which is arranged to engage a master cam 301 on the master camshaft 240. The master cam roller 300 is rotatably mounted on a stud 302 which is supported on the end of a slidably mounted member 303 which may be adjusted relatively toward and from the master cam 301 by means of an adjusting screw 304.

A spring 305 contained within a longitudinally extending slot 306 in the slide 276 is connected at one end to a stud 307 carried by the slide 276 and at the other end to an adjustably positioned stud 308 carried by the cam lapping arm frame 270, a series of spaced holes being provided for the stud 308 so that the tension of the spring 305 may be varied as desired. The spring 305 serves to maintain the master cam follower roller 300 in operative engagement with the surface of the master cam 301 during the lapping operation.

It is one object of the invention to utilize a flexible abrading member to produce the lapping operation. In the preferred form, a flexible abrading cloth or paper is utilized and arranged so that a fresh abrading surface may be provided at intervals during the operation of the machine. The transverse slide 276 is provided with a nose member 309 which is fixedly mounted on the forward end of the slide 276. The nose member 309 carries a yieldably mounted support 310 which serves as a support for the abrading member when in contact with the work. A roll 315 of flexible abrasive paper or cloth 316 is rotatably supported on a shaft 317 which is in turn supported by brackets 318 and 319 on the arms 210 and 211 respectively. The strip of abrasive paper 316 is passed underneath the slide 215 or 216 and extends toward the front of the machine and around the yieldable member 310 of the nose 309 and is fastened to and wound up on a spool 320 carried by a stud 321 which is supported by a bracket 322 carried by the cam lapping arm 270. A rachet wheel 323 carried by the reel 320 and a pawl 324 carried by the arm 322 serve to prevent turning of the reel 320 of worn abrasive paper except in a direction to wind up additional abrasive paper. Side guide plates 311 and 312 are mounted on each side of the nose piece 309 to serve as a guide for the abrasive strip 316.

In order to prevent slipping of the abrasive paper 316 relative to the nose 309 during the lapping operation, a strip of fairly coarse flexible abrasive cloth 325 extends around the end of the nose piece 309 and is clamped in place thereon by means of a clamping member 326 and 327. The yieldably mounted nose piece 310 is held in a forward position by means of a spring 328. This spring permits the nose piece 310 to be held in yielding engagement with the periphery of the cam being lapped.

In order that the abrasive paper and the cam being lapped may be provided with the same relative motion as transmitted by the master cam 301 and its follower roller 300, the yieldable member 310 of the nose 309 is preferably made of a size so that the member 310 together with the flexible abrasive backing and the flexible abrasive lapping paper will form a curvature of substantially the same radius as that of the master cam roller 300. It is readily apparent from this disclosure that any movement transmitted by the master cam 301 and the follower roller 300 is transmitted transversely by the slide 276 to the nose piece 309 to lap or polish a cam on the synchronously rotated camshaft 24 to the desired finish and contour.

In order that the main bearings for the camshaft 24 may be lapped simultaneously with the cams on the shaft, a series of bearing lapping arms are provided which correspond in number with the bearings to be lapped. In the present case, there are three main bearings 330, 331 and 332, each of which is lapped simultaneously by means of a plurality of bearing lapping arms 335.

The bearing lapping arms **335** are each carried by the supporting frames **244**, **226** and **245** which are supported on the guide bars **213** and **214**. Each of the crank arm supporting frames is provided with a vertically extending arm **337** (Fig. 7) which is connected by a stud **338** with the supporting frames **244**, **226** and **245**. The upper end of the arm **337** is provided with a stud **339** which supports the bearing lapping arm **335**.

The bearing lapping arm **335** is provided with a pair of pivotally mounted lapping arms **340** and **341** which are provided at their operating ends with a partially cylindrical lap supporting block **342** and **343**, respectively. The other ends of the arms **340** and **341** are connected by toggle levers **344** and **345** which are in turn connected by a link **346** with an actuating lever **347**. The lever **347** is pivotally mounted on a stud **348** carried by the lapping arm **335**. When the lever **347** is in the position illustrated in Fig. 7, the lap supporting blocks **342** and **343** are in position to hold flexible abrasive cloth or paper **316** in lapping engagement with the bearing being lapped. After the lapping operation has been completed, the lever **347** is rocked in a clockwise direction (Fig. 7) against the tension of a spring **349** which serves to actuate the toggle levers **344** and **345** and to separate the lap supporting blocks **342** and **343** from engagement with the bearings being lapped.

A flexible abrasive cloth or paper **316** is utilized in connection with the bearing lapping arms **335** which is identical with that used in connection with the cam lapping arms **270**. The lap supporting members **342** and **343** are also covered with a strip of relatively coarse abrasive cloth which is clamped in place and serves as a friction device to prevent slipping of the abrasive paper during the lapping or polishing operation. It is not believed to be necessary to describe in detail the arrangement of the spool for supporting the abrasive paper nor the spool for winding up the used abrasive paper since these are identical to those used in connection with the cam lapping arm and the corresponding reference numerals have, therefore, been applied to the corresponding parts in the drawings.

In order to facilitate loading of camshafts **24** into the machine and removal of finish lapped camshafts therefrom, it is desirable to move the entire assembly of cam lapping arms **270** and bearing lapping arms **335** simultaneously to an inoperative position. It is, therefore, desirable to provide a readily operable means for rocking the arms **210** and **211** on the rock shaft **212** so that the entire assembly of lapping arms may be rocked simultaneously in a counterclockwise direction about the shaft **212** as a pivot. The arms **210** and **211** are each provided with a locating surface **350** which engages a surface **351** on the base **20** to locate the arms **210** and **211** in an operative position with the cam lapping arms **270** and the bearing lapping arms **335** in operative position with relation to the camshaft **24** to be lapped.

In order to move the entire assembly to an inoperative position, a fluid pressure mechanism is provided. A fluid pressure cylinder **360** is pivotally connected by means of a stud **361** within the base **20**. A slidably mounted piston **362** is contained within the cylinder **360** and is connected to one end of a piston rod **363**. The other end of the piston rod **363** is connected by a pin **364** with an arm **365** pivotally mounted on a shaft **366** within the base **20**. The arm **365** is provided with a stud **367** which also is connected to one end of a link **368**. The other end of the link **368** is connected by a stud **369** with toggle levers **370** and **371**. The toggle lever **370** is connected by a stud **372** with the base **20**, and the toggle lever **371** is connected by a stud **373** with an arm **374** which is mounted on the rock shaft **212** and arranged to rock the shaft **212** together with the arms **210** and **211** and all of the cam lapping arms **270** and bearing lapping arms **335** together with their supporting and actuating mechanisms either into or away from an operative position.

A fluid pressure system is provided to control the admission of fluid under pressure to the cylinder **360**. A pump **380** within the base **20** of the machine draws fluid through a pipe **381** from a reservoir **382** within the base **20** of the machine and passes fluid under pressure through a pipe **383** to a reverse or control valve **384**. The valve **384** is of a balanced piston type having a valve stem **385** which is connected at its outer end with a control lever **386**. The control valve **384** is connected by pipes **387** and **388** with cylinder chambers **389** and **390**, respectively. In the position of the valve **384** (Fig. 7), the valve is in a neutral position so that no fluid passes to the cylinder **360**. When it is desired to move the lapping arm assembly to an inoperative position, the lever **386** is rocked in a counterclockwise direction so that fluid under pressure passing through the pipe **383** passes through pipe **387** into cylinder chamber **389** and causes the piston **362** to move upwardly within the cylinder **360** and causes the toggle levers **370** and **371** to move into broken line positions **370***a* and **371***a* which serves to rock the lapping arm assembly to an inoperative position. Similarly, after a camshaft **24** has been inserted in the machine, movement of the lever **386** in a clockwise direction (Fig. 7) serves to admit fluid through the pipe **388** into cylinder chamber **390** to cause the piston **362** and the toggle levers **370** and **371** together with their connecting links to move into the full line position (Fig. 7). During the admission of fluid either through the pipe **387** or **388**, fluid is exhausted from the inactive side of the piston **362** through a pipe **391** into the reservoir **382**.

To facilitate loading of the machine, that is removal of a lapped piece of work from the machine and loading a new piece of work therein, it is desirable to provide means for automatically moving the work driver **86** toward the left when the lapping arms are moved to an inoperative position. This is preferably accomplished by connecting a link chain **400** with the lower end of the lever **94**. The link chain **400** passes around an idler pulley **401** and is connected at its other end to the arm **211**. When the lapping arm supports **210** and **211** are moved to an inoperative position, the link chain **400** is moved with the arms, causing the lever **94** and the yoked member **91** to rock in a counterclockwise direction (Fig. 13) to withdraw the work driver **86** from engagement with the end of the camshaft **24** so that the lapped work piece may be readily removed therefrom after the lapping operation has been completed.

Lubricant

In a lapping or polishing operation of this type, it is desirable to apply a cooling and cutting lubricant to the work piece and lapping or polishing element. This is preferably accomplished by means of a lubricant pump **410** which may be

driven by a motor 411 to pass lubricating fluid from a reservoir (not shown) within the base 20 through a pipe 412, a valve 413 which is controlled by a lever 414, and through a pipe 415 to a plurality of valves or nozzles 416 which, as illustrated in Fig. 1, are located directly below the surfaces to be lapped or polished. A separate nozzle or valve 416 is provided to direct cutting lubricant to each of the portions of the work pieces to be lapped. As illustrated in Fig. 1, these nozzles are small petcocks, each of which independently is adjustable so that the desired amount of cutting lubricant may be applied.

It is desirable to stop the flow of cutting lubricant when the machine is in a loading position. A spring 417 connected between the lever 414 and a stud 418 on the base 20 serves to hold the cutting lubricant valve 413 open during the lapping operation. In order automatically to close the valve 413 during the loading interval, a chain 419 is connected between the control lever 414 and the arm 211 which serves as one of the supports for the lapping arm assembly. When the lapping assembly rocks in a clockwise direction to an inoperative position, the arm 211 pulls on the chain 419 and rocks the control lever 414 of the lubricant valve 413 in a clockwise direction to close the valve and thereby stop the flow of coolant fluid during the unloading and loading operation.

In order to simplify the control of the machine and to eliminate unnecessary movements in the control thereof, a connection is provided whereby movement of the footstock center 100 into operative engagement with the end of the camshaft 24 to be lapped serves to actuate the control valve 384 and thereby move the lapping arm assembly, namely the cam lapping arms and bearing lapping arms, immediately into an operative position. A downwardly extending arm 425 which is pivotally connected to the stud 113 connecting the toggle levers 115 and 116 is connected to a pin 426 with links 427. The lower end of the links 427 are provided with a stud 428 which is connected to one end of a lever 429, the other end of which is pivotally mounted on a stud 430 carried by a bracket 431 on the base 20 of the machine. The levers 429 and 386 are each pinned or otherwise affixed to the stud or shaft 430 so that in effect the levers 386 and 429 constitute a bell crank lever. It will readily be apparent from this disclosure that when the lever 130 is shifted to admit fluid to the cylinder chamber 126 to cause the footstock center 100 to move into supporting engagement with the camshaft 24, the movement of the toggle levers 115 and 116 into a straight-line position (Fig. 9) serves to cause a downward movement of the links 427 which serves to rock the bell crank lever 429—386 in a clockwise direction which serves to actuate the fluid pressure control valve 384 so as to pass fluid 388 into cylinder chamber 390 to cause the piston 362 to move into the position illustrated in the drawings, thereby moving the entire assembly of cam lapping and bearing lapping arms into an operative position.

Lap reciprocation

It is desirable to stop the reciprocation of the cam lapping arms when the lapping arm assembly is moved to an inoperative position. An electric switch 440 is provided to control the electric motor 217 which reciprocates the slides 215 and 216. At the start of the lapping operation, a push button 441 is manually pushed to start the motor 217 to reciprocate the cam lapping arms 270. It is desirable automatically to stop the reciprocation after the lapping operation has been completed. At the end of the grinding cycle it is desirable, when the timing mechanism is rendered effective, to stop the rotation of the work piece and automatically and immediately to stop the reciprocation of the lapping elements. The control lever 76 is provided with an outwardly extending arm 442 which carries an adjustable stop screw 443 which is arranged in the path of a push button 444. When the timing mechanism operates to stop the lapping operation, the lever 76 is moved in a clockwise direction (Fig. 14), the stop screw 443 engages the stop button 444 to open the switch 440 and thereby stop the rotation of the motor 217 and the reciprocation of the slides 215 and 216 which support the cam lapping arms 270.

Operation

The operation of this machine will readily be apparent from the foregoing disclosure. A camshaft 24 is positioned within the machine so that its flanged end fits within the recess 88 of the work driving head 86 and so that the driving pin 89 engages a locating hole in the flange on the end of the camshaft 24. The lever 130 is then actuated to shift the footstock control valve 128 to cause the footstock center 100 to move into supporting engagement with the camshaft 24. This movement of the footstock center 100 into operative engagement with the work serves through the toggle levers 115 and 116 and bell crank lever 429—386 to actuate the control valve 384 to move the lapping arm assembly into the operative position (Fig. 7) with the cam lapping arms 270 and the bearing lapping arms 335 adjacent to the surfaces to be lapped. A push button 445 is then operated to start rotation of the motor 43 which rotates the headstock spindle 40. The lever 76 then is moved into the position illustrated in Fig. 14 which serves to move the clutch member 49 toward the right (Fig. 14) to start the rotation of the headstock spindle 40, the camshaft 24 to be lapped, and the master camshaft 240. This movement of the control lever 76 serves not only to start the rotation of the camshaft but also to actuate the push button 441 to close the switch 440 and start the rotation of the motor 217 to cause a reciprocation of the slides 215 and 216 and the cam lapping arms 270 carried thereby.

At the time the cam lapping arm assembly is moved into an operative position, slacking of the chain 400 serves through the lever 93 to rock the work driver 86 toward the right so that it is in supporting engagement with the flange on the end of the camshaft. At the same time, the rocking of the arm 211 into the position illustrated in Fig. 6 serves to open the cutting lubricant valve 413 to supply cooling or cutting lubricant to the camshaft and lapping elements, as desired. The lapping operation continues for a definite number of rotations of the camshaft to which the mechanism has been set. Movement of the clutch 49 from a clutching to a braking position stops the camshaft 24 from rotating as well as reciprocating. The movement of the control lever 76 in a clockwise direction causes the stop screw 443 to actuate the push button 444 to open the switch 440 and stop the rotation of the motor 217 which stops the reciprocation of the cam lapping arms 270. The footstock control lever 130 is then actuated to cause a with-

drawal of the footstock center **100**. This movement serves simultaneously to actuate the valve **384** to cause the arms **210** and **211** which support the lapping arm assembly to move to an inoperative position.

When the lapping arms are moved into an operating position, it is necessary for the operator to actuate the lever **347** on each of the bearing lapping arms **335** to close the lap supporting members **342** and **343** on the bearings to be lapped. Similarly, after the lapping operation has been completed, it is necessary for the operator manually to move all of the levers **347** in a clockwise direction (Fig. 7) to release the lap supporting members **342** and **343** from engagement with the work before the lapping assembly is moved through an inoperative position.

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

We claim:—

1. A camshaft lapping machine having a rotatable camshaft support rotatably to support a camshaft to be lapped, means to rotate a camshaft supported thereon, a movable cam lapping arm, a lapping element on said arm arranged to engage a cam on said camshaft to be lapped, a rotatable master camshaft having a master cam thereon, means to synchronize the rotation of the camshaft and master camshaft, and a follower on said lapping arm which engages a master cam to move the lapping arm transversely so as to maintain the lapping element in uniform lapping engagement with said cam during the lapping operation.

2. A cam shaft lapping machine having a rotatable camshaft support rotatably to support a camshaft to be lapped, means to rotate a camshaft supported thereon, a plurality of movable lapping arms, a lapping element on each of said arms which is arranged to engage a cam on said camshaft to be lapped, a rotatable master camshaft having a plurality of master cams thereon, means to synchronize the rotation of the camshaft and master camshaft, and a follower on each of said arms which engages a master cam independently to move the lapping arms simultaneously to lap a plurality of cams on said shaft.

3. A camshaft lapping machine having a rotatable camshaft support rotatably to support a camshaft to be lapped, means to rotate a camshaft supported thereon, a plurality of transversely movable cam lapping arms, a lapping member on each of said arms which is arranged to engage with a cam to be lapped, a rotatable master camshaft having a plurality of master cams, means to synchronize the rotation of the camshaft and master camshaft, a follower on each of said arms which engages a master cam independently to move the lapping arms transversely to lap simultaneously a plurality of cams, and means relatively to reciprocate said camshaft and cam lapping arms during rotation of said camshaft to produce a predetermined lapping operation on said cams.

4. A camshaft lapping machine having a rotatable camshaft support for supporting a camshaft having a plurality of cams thereon, means to rotate said camshaft, a pair of longitudinally reciprocable slides, a plurality of movable cam lapping arms on each of said slides, a lapping element on each of said arms which is arranged to engage a cam to be lapped, a master camshaft having a plurality of master cams, a follower on each of said arms which engages a master cam independently to cause a transverse movement of said arms, and means relatively to reciprocate said camshaft and cam lapping arms during rotation of said camshaft to produce a predetermined lapping operation.

5. A camshaft lapping machine having a rotatable camshaft support for supporting a camshaft having a plurality of cams thereon, means to rotate said camshaft, a pair of longitudinally reciprocable slides, a plurality of movable cam lapping arms on each of said slides, a lapping element on each of said arms which is arranged to engage a cam to be lapped, a master camshaft having a plurality of master cams, a follower on each of said arms which engages a master cam independently to cause a transverse movement of said arms, and means to reciprocate said slides simultaneously in opposite directions to cause said cam-shaft and cam lapping arms during rotation of said camshaft to produce a predetermined lapping operation.

6. A camshaft lapping machine having a rotatable camshaft support for supporting a camshaft having a plurality of cams thereon, means to rotate said camshaft, a plurality of spaced longitudinally reciprocable slides, a plurality of transversely movable cam lapping arms on each of said slides, a lapping element on each of said arms which is arranged to engage a cam to be lapped, a master camshaft having a plurality of master cams thereon, means synchronously to rotate the camshaft and master camshaft, a follower on each of said arms which engages a master cam independently to cause a transverse movement of said arm, and a yieldable support for each of the lapping elements on said arms which serves to maintain the lapping elements in engagement with the cams being lapped at the desired pressure.

7. A camshaft lapping machine comprising a rotatable camshaft support for a camshaft having a plurality of cams thereon, a plurality of movable cam lapping arms each arranged to engage a cam to be lapped, a master camshaft having a plurality of master cams thereon, means to rotate said camshaft and said master camshaft in synchronism, a follower on each of said arms which engages a master cam independently to control the transverse movement of said arms, a yieldably mounted nose piece on each of said arms, and a flexible abrasive strip wrapped around each of said nose pieces to engage and simultaneously lap all of said cams.

8. A camshaft lapping machine having a rotatable camshaft support including a headstock and a footstock for supporting a camshaft having a plurality of cams thereon, a pair of spaced longitudinally reciprocable slides, a plurality of movable cam lapping arms on each of said slides, each arm being arranged to engage a cam to be lapped, a master camshaft having a plurality of master cams, a follower on each of said arms which engages a master cam independently to cause a transverse movement of said arms, a yieldably mounted nose piece on each of said arms, a flexible abrasive strip around each of said nose pieces

to engage and simultaneously lap all of said cams, and means simultaneously to reciprocate said slides and lapping arms in opposite directions at a rapid rate.

9. A camshaft lapping machine having a rotatable camshaft support, a pivotally mounted frame, a pair of spaced longitudinally reciprocable slides on said frame, a plurality of transversely movable cam lapping arms on each of said slides, a lapping element on each of said arms which is arranged to engage a cam to be lapped, a master camshaft carried by said frame and having a plurality of master cams, means synchronously to rotate the camshaft and master camshaft, a follower on each of said arms arranged to engage a master cam independently to cause a transverse movement of said arms, means to reciprocate said slides simultaneously in opposite directions, means including a fluid pressure operated piston and cylinder to move said frame to and from an operating position, and a fluid pressure system including a control valve which is arranged to admit fluid under pressure to cause said frame to move either to or from an operative position.

10. A camshaft lapping machine having a rotatable camshaft support including a headstock having a rotatable spindle to support said work, a fluid pressure operated footstock which is arranged to support the other end of a camshaft, a fluid pressure control valve operatively connected to move said footstock either into or out of engagement with a camshaft, means to rotate said headstock spindle, a movable frame on said machine, a plurality of transversely movable lapping arms carried by said frame each of which is arranged to engage a cam to be lapped, a master camshaft having a plurality of master cams, means to rotate said master camshaft synchronously with the camshaft, a follower on each of said arms which engages a master cam independently to cause a transverse movement of said arms during a lapping operation, fluid pressure operated means including a piston and cylinder operatively connected to move said frame to position said cam lapping arms either in an operative or inoperative position, a control valve for said cylinder, and connections between said footstock and said control valve whereby the control valve is shifted to move said frame into an operative position when the footstock is moved into supporting engagement with a camshaft.

11. A camshaft lapping machine having a rotatable camshaft support including a headstock having a rotatable spindle to support said work, a fluid pressure operated footstock which is arranged to support the other end of a camshaft, a fluid pressure control valve operatively connected to move said footstock either into or out of engagement with a camshaft, means to rotate said headstock spindle, a movable frame on said machine, a plurality of transversely movable lapping arms carried by said frame each of which is arranged to engage a cam to be lapped, a master camshaft having a plurality of master cams, means to rotate said master camshaft synchronously with the camshaft, a follower on each of said arms which engages a master cam independently to cause a transverse movement of said arms during a lapping operation, fluid pressure operated means including a piston and cylinder operatively connected to move said frame to position said cam lapping arms either in an operative or inoperative position, a control valve for said cylinder, and connections between said control valve and the footstock which are arranged to shift said control valve to cause the frame to move to an inoperative position when the footstock is withdrawn from supporting engagement with a camshaft after a lapping operation.

12. A camshaft lapping machine having a rotatable camshaft support arranged rotatably to support a camshaft having a plurality of cams thereon, a plurality of cam lapping arms, a yieldably mounted nose member on each of said arms to support a lapping element, a lapping element supported by each of said nose members, a movable frame on said machine which is arranged to support said lapping arms, a master camshaft supported thereon having a plurality of master cams, means synchronously to rotate the camshaft and master camshaft, a follower on each of said arms which engages a master cam independently to cause a transverse movement of said arms during a lapping operation, means including toggle levers to move said frame to and from an operating position and to lock said frame in a predetermined operating position with all of said nose pieces under a predetermined pressure, and a fluid pressure system including a piston and cylinder mechanism arranged to actuate said toggle levers to move the frame and lapping arms to and from an operating position.

13. A camshaft lapping machine having a rotatable camshaft support arranged rotatably to support a camshaft having a plurality of cams thereon, a plurality of cam lapping arms, a yieldably mounted nose member on each of said arms to support a lapping element, a lapping element supported by each of said nose members, a movable frame on said machine which is arranged to support said lapping arms, a master camshaft supported thereon having a plurality of master cams, means synchronously to rotate the camshaft and master camshaft, a follower on each of said arms which engages a master cam independently to cause a transverse movement of said arms during a lapping operation, means including toggle levers to move said frame to and from an operating position and to lock said frame in a predetermined operating position with all of said nose pieces under a predetermined pressure, a piston and cylinder operatively connected to actuate said toggle levers to position said frame and cam lapping arms either in an operative or inoperative position, and a control valve which is arranged to control the admission of fluid under pressure to said cylinder.

14. A camshaft lapping machine comprising a rotatable camshaft support to support a camshaft having a plurality of cams thereon, a pivotally mounted frame, a plurality of transversely movable cam lapping arms each having a yieldable nose member, a lapping element on each of said nose members each arranged to engage a cam on said camshaft, a plurality of bearing lapping arms on said frame, a lapping element carried by each of said bearing lapping arms and arranged to engage a bearing surface on said camshaft, means including toggle levers which are arranged to move said pivotally mounted frame to and from a predetermined operating position and to apply a predetermined pressure to said nose pieces when in an operating position, and a fluid pressure actuated mechanism including a piston and cylinder to move the frame to and from an operating position.

15. A camshaft lapping machine comprising a rotatable camshaft support including a head and

footstock, a rotatable headstock spindle, means including a clutch to rotate said spindle, a plurality of transversely movable cam lapping arms, a master camshaft having a plurality of master cams each arranged to move one of said lapping arms, a follower on each of said arms in engagement with a master cam, means to synchronize the rotation of said headstock spindle and master camshaft, a longitudinally reciprocable slide to support said lapping arms, means including an electric motor to reciprocate said slide rapidly to cause a reciprocation between the cam lapping arms and the rotatable camshaft support to produce the desired lapping action, means including an electric switch to start said reciprocating motor at the start of a lapping operation, means automatically to disengage said clutch after a predetermined lapping operation has been completed, and means actuated upon disengagement of said clutch automatically to actuate said switch to stop said motor and the reciprocation of said lapping arms.

16. A camshaft lapping machine comprising a rotatable camshaft support including a headstock and a footstock rotatably to support the opposite ends of a camshaft having a plurality of cams thereon, means to rotate said camshaft, a plurality of transversely movable cam lapping arms, a lapping element on each of said arms which is arranged to engage a cam to be lapped, a master camshaft having a plurality of cams thereon, means to rotate said camshaft and master camshaft in synchronism, a follower on each of said arms which engages a master cam independently to control the transverse movement of said cam lapping arms, means to reciprocate said cam lapping arms during rotation of said shaft to cause a lapping operation on said cams, a plurality of bearing lapping arms each having a lapping element arranged to engage and lap a bearing on said camshaft, and means to reciprocate said work support during the lapping operation to cause a lapping action between the bearing lapping arms and the bearings and to produce a further relative motion between the cams and the cam lapping arms to increase the lapping action therebetween.

17. A camshaft lapping machine comprising a rotatable camshaft support including a headstock and a footstock, a plurality of transversely movable cam lapping arms, a lapping element carried by each of said arms and arranged to engage a cam to be lapped, a master camshaft having a plurality of master cams thereon each arranged to move one of said lapping arms, a follower on each of said lapping arms in engagement with a master cam, means to rotate said master camshaft in synchronism with the rotation of the camshaft being lapped, means to reciprocate said lapping arms rapidly during rotation of said camshaft to produce a lapping action thereon, a plurality of bearing lapping arms, a lapping element carried by each of said arms and arranged to engage a bearing on said camshaft, means to reciprocate said work support to cause a relative longitudinal movement between the bearing lapping arms and the bearings being lapped and to increase the relative longitudinal movement between the cam lapping arms and the cams being lapped, a pivotally mounted support which supports the cam lapping and bearing lapping arms, a fluid pressure operated cylinder and piston operatively connected to move said lapping arms to and from an operating position, and a manually operable control valve which admits fluid under pressure to cause said cam and bearing lapping arms to move either into or away from an operative position.

18. A camshaft lapping machine comprising a rotatable camshaft support including a headstock and a footstock, a movably mounted frame, a plurality of cam lapping arms carried by said frame, a lapping element on each of said arms which is arranged to engage a cam to be lapped, a plurality of bearing lapping arms on said frame, a lapping element carried by each of said arms and arranged to engage a bearing to be lapped, means to cause a relative reciprocation between said work support, cam and bearing lapping arms, a movable frame to support said cam and bearing lapping arms, means including a fluid pressure operated cylinder and piston to move said frame to position the cam lapping and bearing lapping arms either in an operative or inoperative position, a valve operatively connected to control the admission of fluid under pressure to said piston and cylinder, a coolant fluid system including a plurality of nozzles arranged simultaneously to convey a coolant fluid to each of said lapping elements, cams and bearings, a valve arranged to stop and start the flow of coolant fluid, and connections between said valve and said frame whereby the fluid is turned on when the frame moves the lapping arms into an operative position and closes the valve when the frame moves the lapping arms to an inoperative position so that the coolant fluid is automatically cut off during the loading of the machine.

19. A cam lapping arm comprising a supporting frame, a movable arm carried by said frame, a master cam to control the movement of said arm, a follower on said arm, yieldable means interposed between said arm and said frame to maintain the follower in engagement with said cam, a yieldable nose on said cam, and an abrasive lapping element supported on said nose to produce a predetermined lapping operation.

20. A cam lapping arm comprising a frame, a transversely movable arm carried thereby, anti-friction supports for said arm, means to adjust said anti-friction supports to take up lost motion in said parts, a cam to move said arm transversely, a follower on said arm arranged to engage said cam, a spring interposed between said arm and frame to maintain said follower in engagement with said cam, a yieldably mounted nose on said cam, a side guide adjacent to said nose, a flexible abrasive lapping element between said guides and wrapped around said nose, and means to supply a fresh portion of abrasive when desired.

21. A cam lapping arm comprising a frame, a transversely movable arm carried by said frame, an adjustable anti-friction support for said arm interposed between the arm and the frame, a cam to move said arm transversely, a follower on said arm engageable with said cam, yieldable means interposed between said frame and arm to maintain the follower in engagement with said cams, a yieldably mounted nose on said arm, a reel of flexible abrasive carried by said arm and arranged to wrap around said nose, side guides on said nose to locate abrasive relative to the nose, means to adjust the tension of said yieldable nose, and means to adjust the position of said follower to position the nose in the desired position.

HERBERT S. INDGE.
GEORGE E. HULBERT.