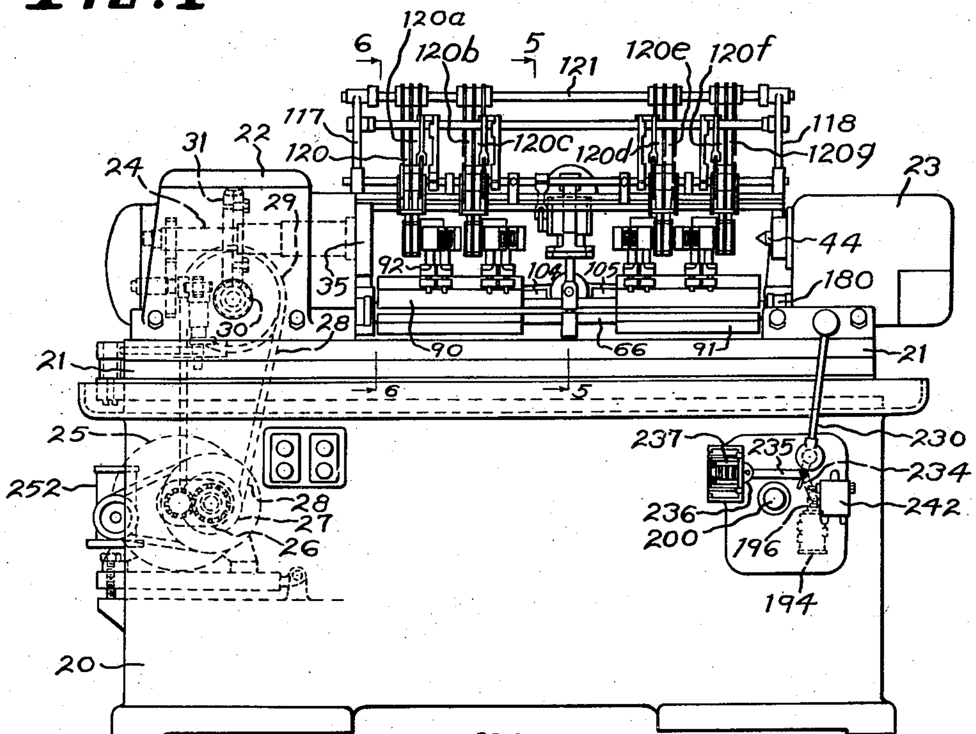
April 17, 1945. H. S. INDGE ET AL 2,373,640

CAM LAPPING MACHINE

Filed June 26, 1943 7 Sheets-Sheet 1

FIG. 1



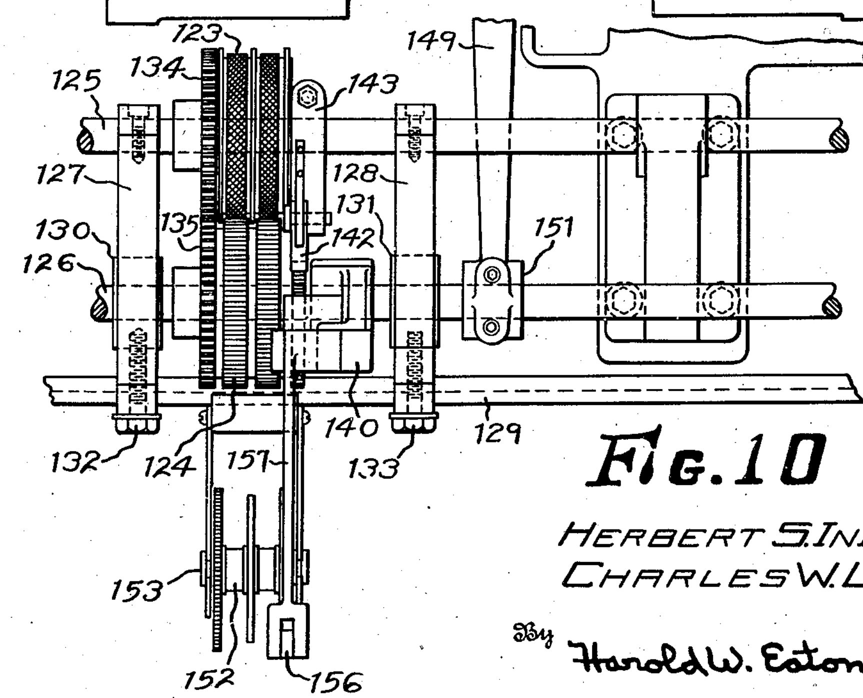


FIG. 10

Inventors

HERBERT S. INDGE

CHARLES W. LUND

By Harold W. Eaton

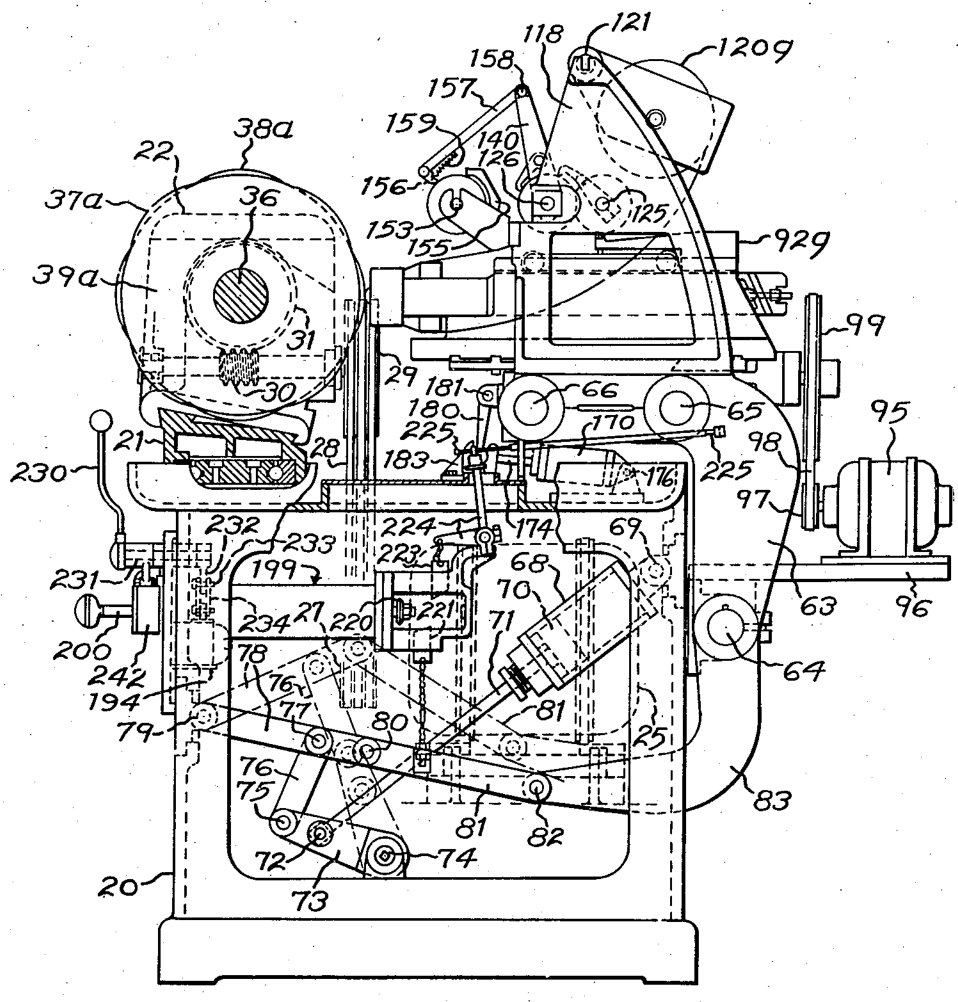
Attorney

April 17, 1945. H. S. INDGE ET AL 2,373,640

CAM LAPPING MACHINE

Filed June 26, 1943 7 Sheets-Sheet 2

FIG. 2



Inventors

HERBERT S. INDGE
CHARLES W. LUND

By Harold W. Eaton Attorney

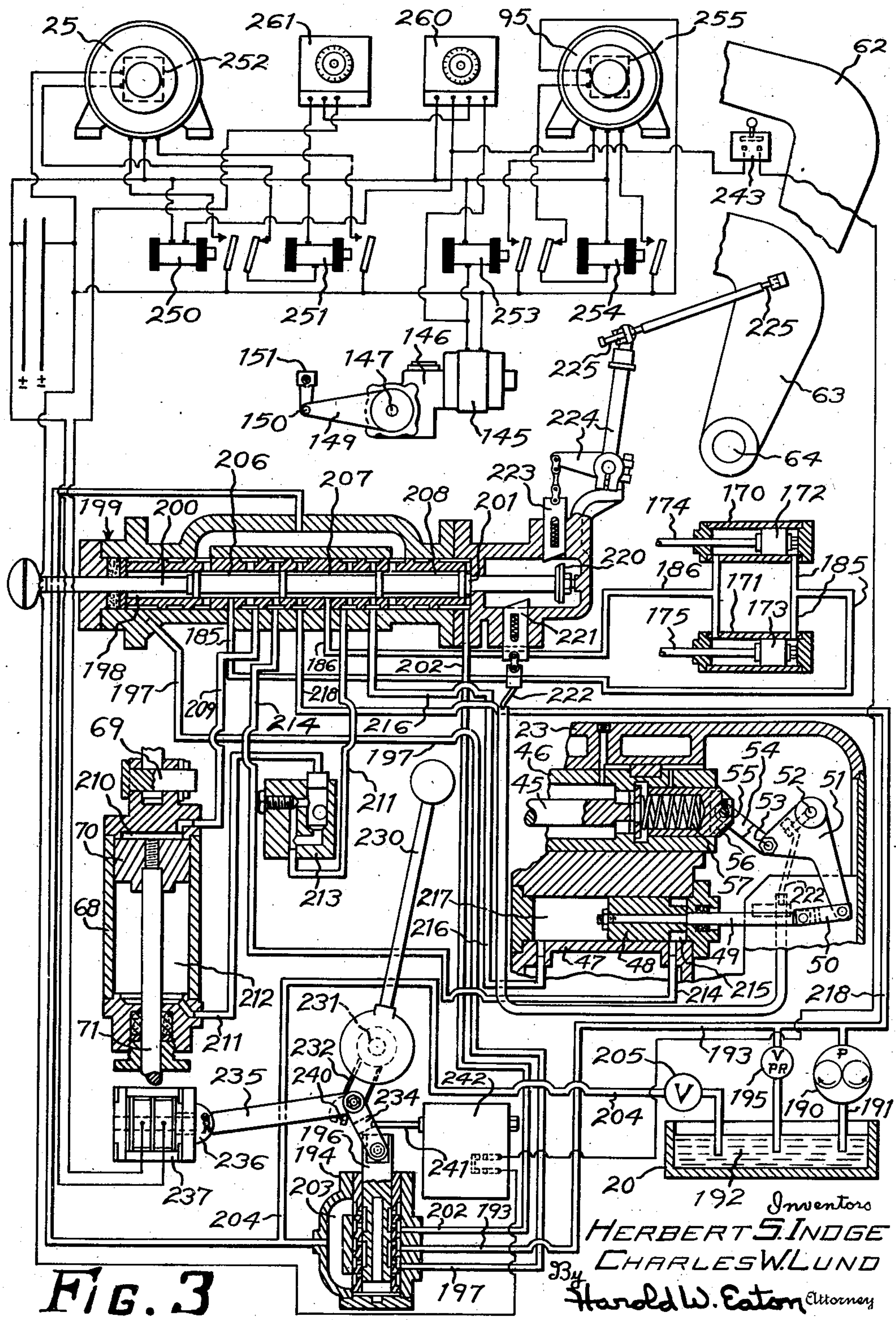
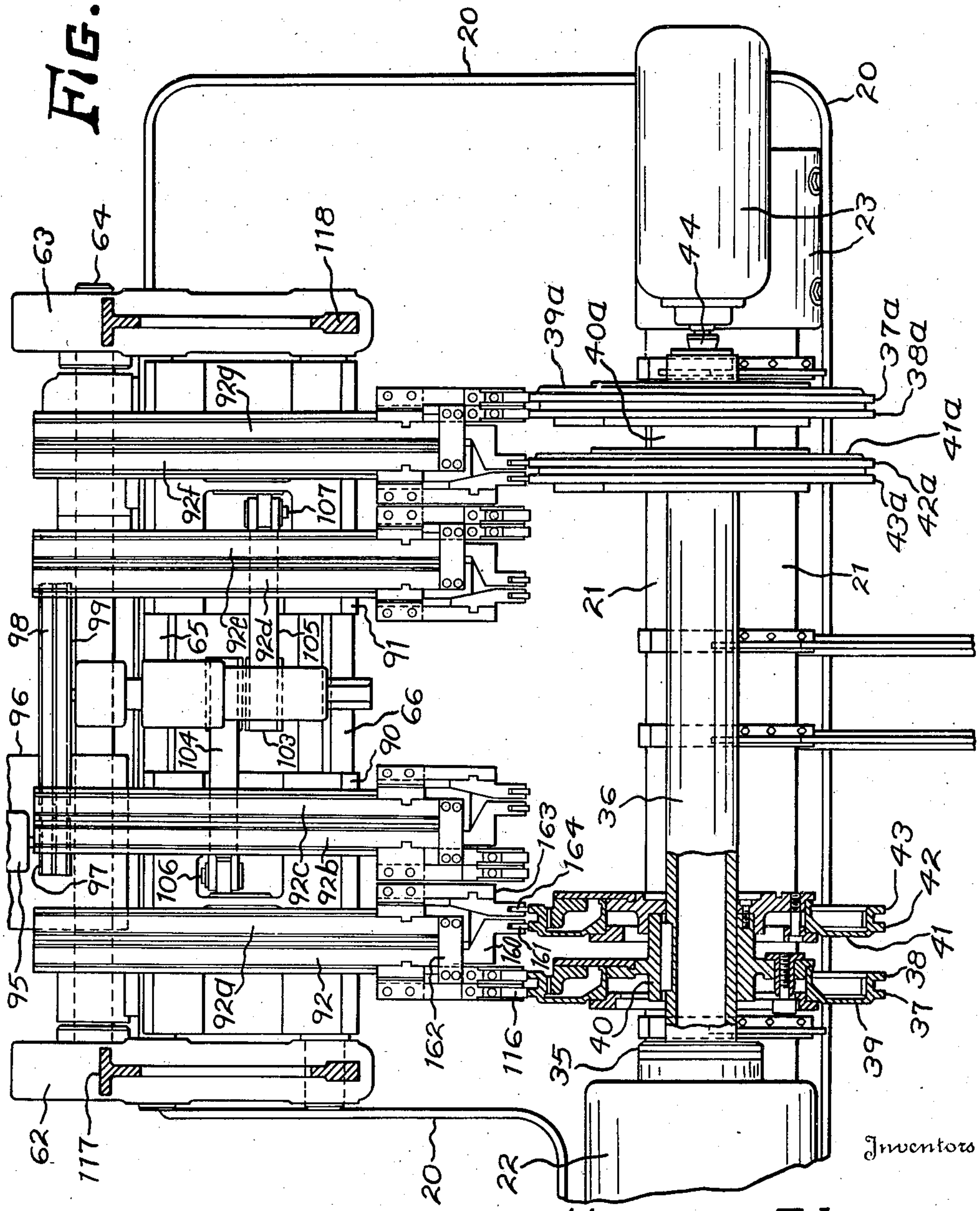


FIG. 3

Inventors
HERBERT S. INDGE
CHARLES W. LUND
By Harold W. Eaton Attorney

FIG. 4



Inventors

HERBERT S. INDGE

CHARLES W. LUND

By Harold W. Eaton Attorney

April 17, 1945. H. S. INDGE ET AL 2,373,640

CAM LAPPING MACHINE

Filed June 26, 1943 7 Sheets-Sheet 5

FIG. 5

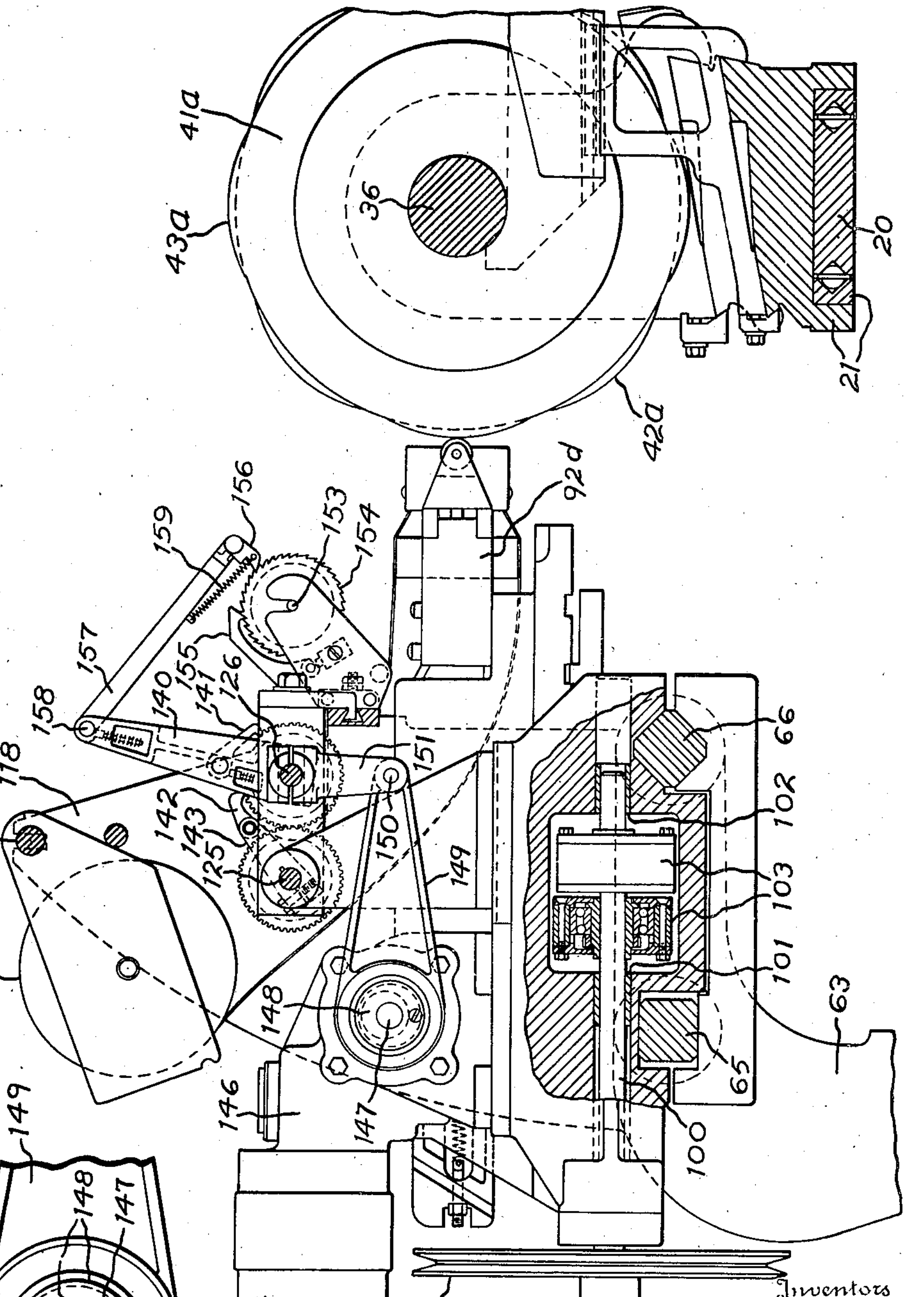
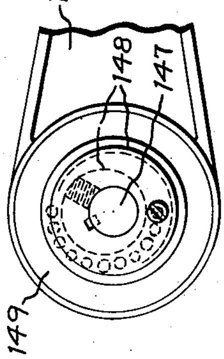


FIG. 11



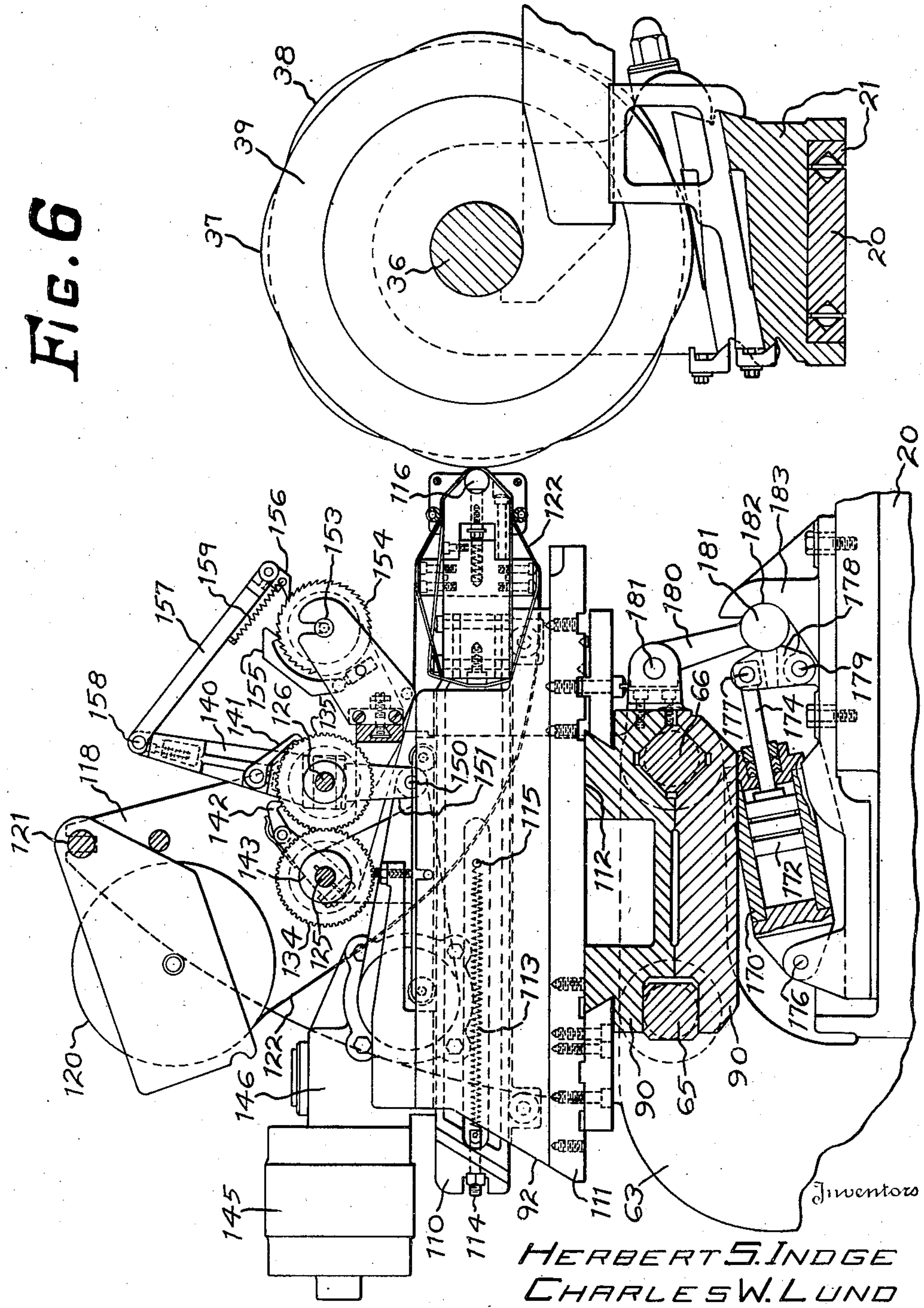
Inventors

HERBERT S. INDGE
CHARLES W. LUND

By Harold W. Eaton Attorney

April 17, 1945. H. S. INDGE ET AL 2,373,640
CAM LAPPING MACHINE
Filed June 26, 1943 7 Sheets-Sheet 6

FIG. 6



Inventors
HERBERT S. INDGE
CHARLES W. LUND
By Harold W. Eaton Attorney

FIG. 8

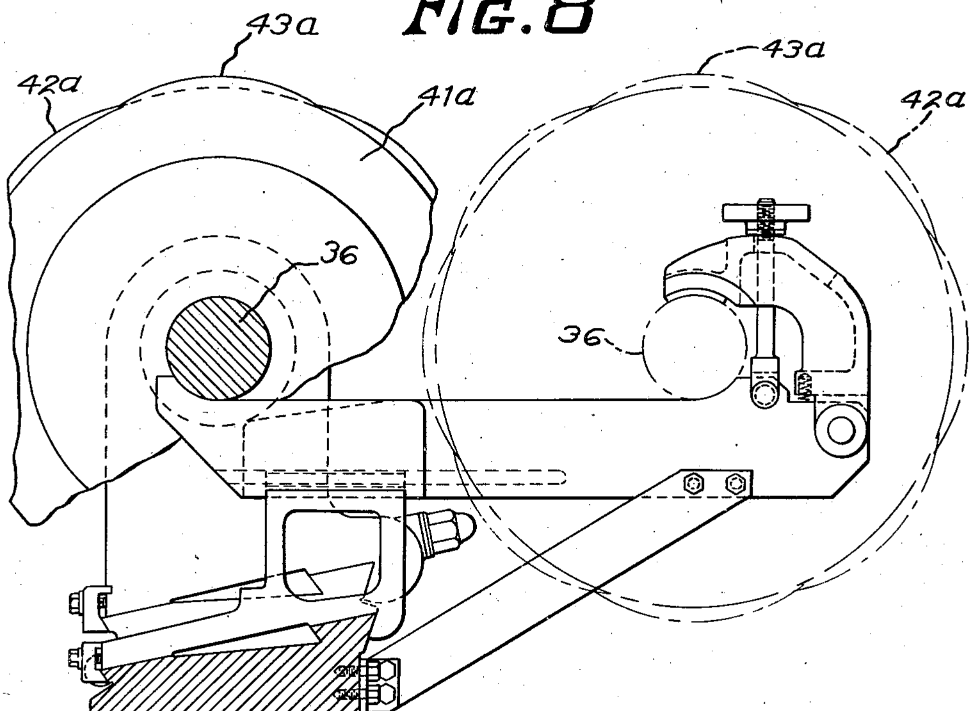
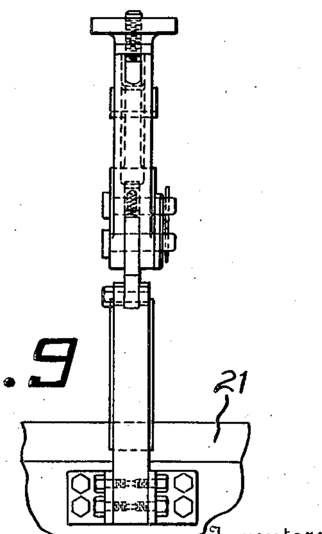


FIG. 7

FIG. 9



Inventors

HERBERT S. INDGE
CHARLES W. LUND

By Harold W. Eaton Attorney

Patented Apr. 17, 1945 2,373,640

UNITED STATES PATENT OFFICE

2,373,640

CAM LAPPING MACHINE

Herbert S. Indge, Westboro, and Charles W. Lund, Boylston, Mass., assignors to Norton Company, Worcester, Mass., a corporation of Massachusetts

Application June 26, 1943, Serial No. 492,436

11 Claims. (Cl. 51—64)

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

One object of the invention is to provide a simple and thoroughly practical lapping machine for simultaneously lapping a plurality of cams. A further object of the invention is to provide an automatic cam lapping machine with a plurality of lapping arms each of which is arranged to lap a cam. Another object of the invention is to provide a cam lapping machine with an automatically actuated abrasive paper feed which continuously presents a fresh abrading surface during a lapping operation.

A further object of the invention is to provide a cam lapping machine in which the lapping arm is controlled by a master cam positioned in axial alignment with and rotatable with the cam being lapped, thus eliminating the necessity for a synchronous driving mechanism between the master cam and the cam to be lapped. Another object of the invention is to provide a cam lapping machine having movable cam lapping arms the movement of which is controlled by master cams mounted on an arbor supporting the cams to be lapped.

A further object of the invention is to provide a cam lapping machine with a lapping arm assembly having a plurality of movable lapping arms supported thereon which is movable toward and from an operative position and which is arranged to be automatically clamped in an operative position during a lapping operation. A further object of the invention is to provide an automatically operated hydraulic clamping mechanism for locking the lapping arm assembly in an operative position during a lapping operation. 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 cam lapping machine;

Fig. 2 is an end elevation, on an enlarged scale, of the improved cam lapping machine;

Fig. 3 is a diagrammatical illustration of the electric wiring and control combined with the hydraulic actuating mechanism;

Fig. 4 is a fragmentary plan view, on an enlarged scale, showing the arrangement of the lapping arms, the master cams and the cams to be lapped;

Fig. 5 is a fragmentary cross-sectional view, on an enlarged scale, taken approximately on the line 5—5 of Fig. 1, showing the paper feeding mechanism for the lapping arm and the lapping arm reciprocating mechanism;

Fig. 6 is a similar fragmentary sectional view, on an enlarged scale, taken approximately on the line 6—6 of Fig. 1 showing the locking mechanism for locking the lapping arm assembly in an operative position;

Fig. 7 is a fragmentary plan view, on an enlarged scale, of the forward ends of a pair of lapping arms;

Fig. 8 is a fragmentary sectional view through the work supporting table showing the work loading cradle in end elevation;

Fig. 9 is a fragmentary front elevation, on an enlarged scale, of one of the work cradles;

Fig. 10 is a fragmentary plan view, on an enlarged scale, of one set of the abrasive paper feeding rollers; and

Fig. 11 is a fragmentary side elevation, on an enlarged scale, showing the adjustable throw eccentric for actuating the abrasive lapping paper feed mechanism.

A cam lapping machine has been illustrated in the drawings comprising a base **20** which supports a longitudinally reciprocable work supporting table **21**. Anti-friction type table ways (Fig. 5) are provided between the base **20** and the table **21** to facilitate free reciprocatory movement of the table **21** relative to the base **20**. The table **21** is provided with a rotatable work support comprising a headstock **22** and a footstock **23**. The headstock **22** is provided with a rotatable spindle **24** which is driven by an electric motor **25**. The motor **25** is equipped with a built-up speed reducing unit **26**. A V-groove pulley **27** is provided on the speed reduction unit **26** which is connected by a multiple V-belt **28** with a multiple V-groove pulley **29** which is mounted on the end of a rotatable worm shaft **30**. The worm **30** in turn meshes with a worm gear **31** which is fixedly supported on the headstock spindle **24**. The headstock spindle **24** is provided with a work driving head **35** which is arranged to engage and drive the left-hand end of a work supporting arbor **36**. The work supporting arbor **36** is arranged to support a plurality of cams **37** and **38** which are formed integral with an annular ring-shaped member **39**. The member **39** is removably supported on a fixture **40** which is fixedly keyed to the work arbor **36**.

In order to avoid the necessity of a synchronized drive between the cam being lapped and the master cam, it is preferable to provide a master cam supported on the work supporting arbor 36 which is of the same size and shape as the cam to be lapped. The work arbor 36 is provided with a supporting plate 41 which is formed integral with a pair of master cams 42 and 43. The plate 41 together with the master cams 42 and 43 are identical with the cams previously described which are to be lapped. The plate 41 is in turn supported on a similar flanged member on the arbor 36 which is fixed relative thereto.

A similar plate 40*a* is mounted on the other end of the work arbor 36 and serves as a support for an annular ring shaped member 39*a* which has formed integrally therewith cams 37*a* and 38*a* to be lapped. A supporting flange 41*a* is provided adjacent to the plate 40*a* on the work supporting arbor 36. The plate 41*a* serves as a support for a pair of master cams 42*a* and 43*a* which are identical in size and shape with the cams 37*a* and 38*a* to be lapped.

The footstock 23 is provided with a footstock center 44 which rotatably supports the right hand end of the work arbor 36. The footstock center 44 is supported in one end of a rotatable spindle 45 which is journalled in bearings (not shown) in a slidably mounted sleeve 46. The sleeve 46 is slidably keyed within a cylindrically shaped aperture formed within the footstock frame 23. The footstock center 44 is preferably moved to and from an operative position by a hydraulically operated mechanism comprising a cylinder 47 which contains a slidably mounted piston 48. The piston 48 is connected to one end of a piston rod 49. The other end of the piston rod 49 is pivotally connected to one end of a link 50 (Fig. 3). The other end of the link 50 is pivotally connected to one arm of a pivotally mounted bell crank lever 51. The bell crank lever 51 is pivotally supported on a stud 52 and the other arm thereof is pivotally connected by means of a stud 53 with one end of a link 54. The other end of a link 54 is connected by a stud 55 with a slidably mounted sleeve 56 which is slidably supported within a cylindrical bore within the sleeve 46. A compression spring 57 is connected by a stud 55 with a slidably mounted sleeve 56 which is slidably supported within a cylindrical bore within the sleeve 46. A compression spring 57 is contained within the sleeve 56 and serves yieldably to maintain the footstock center 44 in an operative position when the bell crank lever 51 is swung to an operative position.

Lapping arm assembly

It is desirable to provide a movable support for a plurality of lapping arms so that they may be simultaneously and quickly moved to and from an operative position. A pair of spaced arms 62 and 63 are mounted on a rock shaft 64 (Fig. 2) which is supported in bearings on the rear of the machine base 20. The arms 62 and 63 are interconnected by a pair of spaced horizontally extending bars 65 and 66 which serve as slide ways for supporting lapping arm slides to be hereinafter described.

The lapping arm assembly supported by the arms 62 and 63 is arranged so that it may automatically move to and from an operative position to facilitate loading of cams to be lapped into the machine and removing them therefrom after a lapping operation has been completed. In order to move the entire lapping arm assembly to and from an inoperative position, a fluid pressure mechanism is provided comprising a fluid pressure cylinder 68 which is pivotally connected by means of a stud 69 which is fixedly mounted within the base 20 of the machine. A piston 70 is slidably mounted within the cylinder 68 and is connected to one end of a piston rod 71. The other end of piston rod 71 is connected by a stud 72 with an arm 73. The arm 73 is pivotally supported on a stud 74 within the base 20. The other end of the arm 73 is connected by a stud 75 to one end of a link 76 which is in turn connected by a stud 77 with a toggle lever 78. The adjacent ends of the toggle lever 78 and a toggle lever 79 are connected by means of a stud 80. The toggle lever 78 is connected at its other end by means of a stud 79 which is fixedly supported within the base 20. The toggle lever 81 is connected by means of a stud 82 with an arm 83 which is fixedly mounted on the rock shaft 64 and is arranged to rock the shaft 64 together with the arms 62 and 63 and the entire lapping arm assembly either to or from an operative position.

The levers above described, as shown in full line position in Fig. 2, are in a position to hold the arm 83 together with the arms 62 and 63 and the entire lapping arm assembly in an operative position. When a lapping operation is completed fluid under pressure is admitted to a chamber in the lower end of the cylinder 68 to cause the piston 70 to move upwardly (Fig. 2) so that the piston rod 71 moves toward the right to shift the levers 73, 76, 78, and 81 into the broken line positions, as indicated in Fig. 2 by the same numerals with the suffix "*a*," so as to move the entire lapping arm assembly to an inoperative position.

A pair of slides 90 and 91 (Fig. 4) are slidably supported on the bars 65 and 66. The slide 90 serves as a support for a plurality of lapping arms 92, 92*a*, 92*b*, and 92*c*. The slide 91 serves as the support for a plurality of lapping arms 92*d*, 92*e*, 92*f*, and 92*g* (Fig. 4).

Lapping arm reciprocation

It is desirable to impart a reciprocatory movement to the lapping arms during a lapping operation. A reciprocating mechanism is provided to simultaneously reciprocate the slides 90 and 91 in opposite directions so as to impart a relative reciprocatory movement between the lapping element and the cams to be lapped. A motor driven reciprocating mechanism is provided comprising an electric motor 95 which is supported on a platen 96. The platen 96 is fixedly supported on the rock shaft 64 and is arranged to move with the arms 62 and 63 to and from an operative position. The motor 95 is provided with a V-groove pulley 97 which is connected by a V-belt 98 with V-groove pulley 99 which is mounted on the rear end of a rotatable shaft 100. The shaft 100 is rotatably journalled in bearings 101 and 102 which are carried by a bracket which is fixed relative to the bars 65 and 66 (Fig. 5). The shaft 100 supports a pair of eccentrics 103 (only one of which has been illustrated in Fig. 3 of the drawings) which are connected by connecting rods 104 and 105 with studs 106 and 107. Studs 106 and 107 are in turn supported by slides 90 and 91 respectively. It will be readily apparent from the foregoing disclosure that when the motor 95 is set in motion, this motion will be transmitted through the mechanism above described simultaneously to reciprocate the slides 90 and 91 in opposite directions.

Lapping arms

Lapping arms **92**, **92a**, **92b**, **92c**, **92d**, **92e**, **92f**, and **92g** are substantially identical in construction, consequently they have not all been illustrated in detail. The lapping arm **92** (Fig. 6) comprises a transversely movable slide **110** which is slidably mounted within a casing **111**. The casing or frame **111** is provided with a dove-tailed slide surface which mates with a correspondingly shaped dove-tailed way formed on the upper surface of the slide **90**. It will be readily apparent from the construction as illustrated in Fig. 6 that each of the lapping arms may be independently adjusted longitudinally relative to the slides **90** and **91** respectively to position the lapping arm in a desired and predetermined relationship with the master cams and cams to be lapped. A tension spring **113** is provided which is connected at one end by means of a stud **114** with the slide **110**. The other end of the spring **113** is connected by a stud **115** with the frame **111**. The tension of the spring **113** normally serves to urge the slide **110** in a forward direction so as to maintain the follower, to be hereinafter described, in operative engagement with the face of the master cam during a lapping operation. The slide **110** is provided with a yieldably mounted nose piece **116** which serves as a support for a continuous strip of abrasive lapping paper.

Abrasive paper-feed

A pair of upwardly extending brackets **117** and **118** are fixedly mounted on the upper portions of the arms **62** and **63** respectively, and serve as a support for the abrasive lapping paper and the feeding mechanism therefor.

An independent roll of continuous flexible abrasive paper **120**, **120a**, **120b**, **120c**, **120d**, **120e**, **120f**, and **120g** is provided for each of the lapping arms. The rolls of abrasive paper are pivotally supported on a shaft **121** which is in turn supported by the upwardly extending brackets **117** and **118** respectively (Figs. 1 and 6).

As shown in Fig. 6, a strip of abrasive paper **122** from the roll of paper **120** passes downwardly around the nose piece **116**. After passing around the nose piece **116** the abrasive paper passes upwardly between a pair of knurled feed rolls **123** and **124** which are rotatably supported on a pair of base parallel shafts **125** and **126** respectively (Figs. 6 and 10). The shaft **125** is fixedly supported at its opposite end in the upwardly extending brackets **117** and **118** respectively. The shaft **126** is adjustably mounted relative to the shaft **125**. A plurality of supporting brackets **127** and **128** are supported on the shaft **125** and are clamped at their other end to a shaft **129**. Slidably mounted journalled blocks **130** and **131** are provided for supporting the shaft **126**. These journals are slidably supported within the brackets **127** and **128** respectively. Adjusting screws **132** and **133** are provided on the brackets **127** and **128** respectively by means of which the journal blocks **130** and **131** may be transversely adjusted to vary the position of the feed roll **124** relative to the feed roll **123**. The feed rollers **123** and **124** are geared together by means of a pair of meshing gears **134** and **135** which are fixedly mounted relative to the feed rollers **123** and **124** respectively.

It is desirable that the abrasive lapping paper be automatically fed during the lapping operation so that a uniform abrading surface is provided during the entire lapping operation. An automatic feeding mechanism is provided comprising a pivotally mounted arm **140** which is supported on the shaft **126**. An actuating pawl **141** is pivotally supported on the oscillatable arm **140**. The arm **140** is oscillated by a mechanism to be hereinafter described. A pivotally mounted holding pawl **142** is supported by a bracket **143** which is fixedly supported on the shaft **125**. This holding pawl **142** serves to prevent a counterclockwise rotation of the gear **135**.

An electrically operated mechanism is provided for actuating the feed pawl **141**. This mechanism may comprise an electric motor **145** (Fig. 5) which is provided with an integrally formed built-in speed reduction unit **146**. This motor driven gear reduction unit may be of any of the standard well known motor driven gear reduction units such as for example the "Bodine" reducer which is operatively connected to rotate a shaft **147**. Shaft **147** is provided with an adjustably mounted eccentric **148**. The eccentric **148** is connected to a connecting rod **149** and a stud **150** with a downwardly extending arm **151** which is formed integral with the oscillatable arm **140**. It will be readily apparent from the foregoing disclosure that rotation of the motor **145** will be transmitted to the gear reduction unit **146** to rotate the shaft **147** and the eccentric **148** to transmit an oscillating movement through the connecting rod **149**, to the arm **151** and the arm **140** continuously to oscillate the feed pawl **141**. The feed pawl **141** rides idly over the teeth on the gear **135** when the arm **140** is moved in a counterclockwise direction. When the arm **140** is moved in a clockwise direction, the feed pawl **141** engaging the teeth of the gear **135** rotates the gear in a clockwise direction (Figs. 5 and 6) to impart a feeding movement to the abrasive lapping paper.

After passing through the feed rolls **123** and **124** the worn out lapping paper is rolled up on a reel **152** which is supported on a shaft **153** (Figs. 5 and 6). A ratchet wheel **154** is provided on the reel **152**. A holding pawl **155** serves to prevent rotation of the reel **152** in a clockwise direction.

A feed pawl **156** is pivotally mounted at the right hand end of a link **157** (Figs. 5 and 6). The other end of the link **157** is connected by a stud **158** with the upper end of the arm **140**. A tension spring **159** serves normally to hold the ratchet pawl **156** in the position illustrated in Figs. 5 and 6. The tension of the spring **159** is preferably sufficient to transmit the desired motion to the reel **152** so that the slack worn out abrasive paper is wound up after which any further motion of the arm **140** will cause the feed pawl **156** to ride idly over the ratchet wheel **154**.

Similar abrasive lapping paper feed rollers together with the automatic feeding mechanism therefor are provided for each of the lapping arms **92**, **92a**, **92b**, **92c**, **92d**, **92e**, **92f**, **92g**. These feed rollers and wind up rollers are all actuated in the same manner by independent pawl and ratchet mechanisms all of which are actuated and driven by the electric motor **145**. Only one of these mechanisms has been illustrated in detail as above described. Any one of the feed mechanisms may be rendered inoperative as desired by throwing the feed and wind up pawls to an inoperative position.

As illustrated in Fig. 4 the work arbor **36** is arranged to lap a pair of cams **37** and **38** at one end of the arbor and a pair of cams **37a** and **38a** located at the other end of the arbor. During this lapping operation the lapping arms **92*b***, **92*c***, **92*d***, **92*e***, are inoperative. A second arbor (not shown) may be provided which may be loaded, while arbor **36** is being lapped with cams positioned in operative relationship with the lapping arms **92*b***, **92*c***, **92*d***, and **92*e*** for the second lapping operation. It will thus be seen that the lapping arms as provided are utilized only on every other lapping operation in the set up illustrated in the drawings. This arrangement is due primarily to the design of the cam to be lapped and the manner in which they must be mounted and located on the arbor for the lapping operation.

The nose piece **116** (Fig. 7) is adjustably mounted on the left hand side face of the lapping arm **92** and is arranged so that it may be adjusted vertically and horizontally relative thereto. The lapping arm **92** is provided with an off set bracket **160** which serves as a support for a master cam roller **161** which engages peripheral surface of the master cam **42**. It will be readily apparent from the foregoing disclosure that motion of the master cam **42** which is mounted on the work arbor **36** will be transmitted through the bracket **160** to impart a controlled transverse movement to the lapping arm **92** so as to impart a corresponding movement to the nose piece **116** which supports the abrasive lapping paper **122**.

The lapping arm **92*a*** is provided with an off set nose piece **116*a*** which is connected by a bracket **162** with the forward end of the lapping arm **92*a***. A bracket **163** is adjustably supported on the side face of the lapping arm **92*a*** and serves as a support for a master cam roller **164**. The bracket **163** is adjustably supported on the lapping arm **92*a*** so that it may be adjusted vertically and also horizontally relative thereto to facilitate timing the master cam follower with the action of the nose piece **116*a*** during lapping operation. It will be readily apparent from the foregoing disclosure that the motion of the master cam **43** will be imparted through the roller **164** and the bracket **163** to the lapping arm **92*a*** which in turn transmits a corresponding movement through the bracket **162** to the nose piece **116*a*** to control the lapping action on the cam **38**.

Each of the pairs of lapping arms **92*b***, **92*c***, **92*d***, **92*e***, **92*f***, and **92*g*** are similarly provided with offset nose pieces and master cam rollers which are designated by the same numerals suffixed with the letters *b*, *c*, *d*, *e*, *f* and *g*. These arrangements are identical with that just described in connection with the lapping arms **92** and **92*a***, consequently it is deemed unnecessary to describe these several units in detail.

In order to overcome the thrust of the master cams and product cams against the lapping arm assembly during a lapping operation, it is desirable to provide a suitable clamping mechanism for clamping the lapping arm assembly in an operative position. In the preferred form, a hydraulically operated clamping mechanism is provided for clamping each of the arms **62** and **63** in an operative position. The clamping mechanism comprises a pair of spaced cylinders **170** and **171** which contain pistons **172** and **173** respectively. The pistons **172** and **173** are fixedly connected to piston rods **174** and **175** respectively (Fig. 3). The cylinder **170** is preferably pivotally supported by a stud **176** which is in turn fixedly supported relative to the base **20** (Fig. 6). The other end of the piston rod **174** is pivotally connected by a stud **177** with the upper end of a pivotally mounted clamping member **178**. The clamping member **178** is pivotally supported by a stud **179** which is fixed relative to the base **20** (Fig. 6). A link **180** is pivotally supported by a stud **181** on the arm **63**. The lower end of the link **180** is provided with a cylindrically shaped member **181** which is arranged to mate with a correspondingly shaped surface **182** formed on a bracket **183**, when the lapping arm assembly is in an operative position (Fig. 6).

The clamping device associated with the arm **62** and cylinder **171** is identical in construction to that just described, consequently it has not been illustrated and described in detail.

After the lapping arm assembly is moved to an operative position, fluid under pressure is admitted through a pipe **185** automatically to move the pistons **172** and **173** to actuate both of the clamping members **178** (only one of which has been illustrated in Fig. 6) to clamp the lapping arm assembly rigidly in an operative position relative to the base **20**.

Hydraulic controls

A hydraulically operated control mechanism is provided for actuating and controlling the various elements of the machine. A motor driven fluid pressure pump **190** is provided for drawing fluid through a pipe **191** from a reservoir **192** and passing fluid under pressure through a pipe **193** to a start and stop valve **194** (Fig. 3). A relief valve **195** is provided to facilitate passing exhaust fluid under pressure from the system directly to the reservoir **192**. The valve **195** is a standard adjustable pressure relief valve and consequently has not been illustrated in detail. The start and stop valve **194** is a piston type valve comprising a valve stem **196** having a plurality of valve pistons formed integrally therewith. In the position of the valve **194** (Fig. 3) fluid under pressure passing through the pipe **193** passes outwardly through a pipe **197** into an end chamber **198** in a piston type control valve **199**. The valve **199** comprises a valve stem **200** having a plurality of valve pistons formed integrally therewith. An end chamber **201** of the valve **199** is connected by a pipe **202** with the start and stop valve **194** and as shown in Fig. 3 is connected so as to exhaust fluid from the chamber **201** through a passage **203** and a pipe **204** into the reservoir **192**. It will be readily apparent from the foregoing disclosure that the start and stop valve **194** serves to control the admission of fluid under pressure to and from the end chambers **198** and **201** of the control valve **199** to shift the valve stem **200** either toward the right (Fig. 3) into the position illustrated in the drawings, at the end of the lapping cycle, or to shift the valve stem **200** toward the left to initiate a lapping cycle. An adjustable valve **205** is provided in the pipe line **204** to facilitate controlling the exhaust of fluid from the end chambers **198** and **201** of the control valve **199** so as to control the rate of movement of the valve stem **200** when it is moved in either direction.

The control valve **199** is operatively connected to control the admission of fluid under pressure to the cylinder **68** to cause a movement of the lapping arm assembly to and from an operative position, to the cylinder **47** to actuate the footstock center, and also to the cylinders **170** and **171** to actuate the clamping mechanism to clamp the lapping arm assembly in an operative position.

The control valve **199** is provided with valve chambers **206**, **207**, and **208**. The valve chamber **206** is connected by pipe **209** with a chamber **210** formed in the upper end of the cylinder **68**. The chamber 207 of the valve 199 is connected by a pipe 211 with a chamber 212 formed at the lower end of the cylinder 68. A combined check and throttle valve 213 is provided in the pipe line 211 which is arranged to allow substantially unrestricted passage of fluid through the pipe 211 when fluid under pressure is admitted to the cylinder chamber 212 to cause the lapping arm assembly to move rapidly to an inoperative position, but is arranged so that a desired controlled rate of movement may be obtained when the lapping arm assembly is moved to an operative position.

Similarly the valve chamber 206 is connected by a pipe 214 with a cylinder chamber 215 in the footstock chamber 47. The valve chamber 207 is connected by a pipe 216 with a cylinder chamber 217. It will be readily apparent from the foregoing disclosure that the control valve 199 serves to control admission to or exhaust of fluid from the opposite ends of the cylinder 47 to actuate the footstock center 45.

The valve chamber 206 is also connected by a pipe 185 with the cylinder chambers formed at the right hand end of the cylinder 170 and 171 (Fig. 3) to move the clamping members to clamp the lapping arm assembly in an operative position. The valve chamber 207 is also connected by a pipe 186 with cylinder chambers formed at the left hand ends of the cylinders 170 and 171 (Fig. 3). It will be readily apparent from the foregoing disclosure that the valve 199 controls the admission to and exhaust of fluid from the clamping cylinders 170 and 171 respectively in timed relationship with the other mechanisms of the machine.

The valve chamber 207 of the control valve 199 is connected by a pipe 218 with the fluid pressure pump 190 so that fluid under pressure is continuously admitted to the valve chamber 207.

Interlock

An interlock mechanism is provided which cooperates with the movement of the control valve 199 to prevent movement of the lapping arm assembly into an operative position before the footstock center 45 is moved into operative engagement to position a work piece to be lapped. This mechanism comprises a flange 220 which is fixedly mounted adjacent to the end of the valve stem 200. A spring pressed detent 221 normally lies in the path of the flange 220. The detent 221 is connected by means of a flexible cable 222 with the bell crank lever 51. When fluid under pressure is passed into the cylinder chamber 215 of the cylinder 47 to rock the bell crank lever 51 in a clockwise direction to move the footstock center 45 into an operative position, this movement moves the cable 222 to withdraw the detent 221 out of the path of the flange 220. It will be readily apparent from the foregoing disclosure that unless the footstock center 45 has moved into an operative position, the valve stem 200 cannot be shifted toward the lever a sufficient distance to admit fluid under pressure through the pipe 209 to cause a downward movement of the piston 70 to move the lapping arm assembly into an operative position.

A similar spring pressed detent 223 is provided which lies in the path of the flange 220 during a lapping operation. The detent 223 is connected to a pivotally mounted bell crank lever 224 the upper end of which is connected by a link 225 (Fig. 3) with the arm 63. The detent 223 serves to prevent movement of the flange 220 and the valve 200 toward the right to prevent withdrawal of the footstock center 45 before the lapping arm assembly has been moved to an inoperative position.

Control lever

A manually operable control lever 230 is fixedly mounted on the outer end of a rock shaft 231. A downwardly extending arm 232, mounted on the inner end of the rock shaft 231, is connected by a stud to the upper end of a link 234 to cause a downward movement of the valve stem 196 which shifts the valve pistons of the valve 194 downwardly so that fluid under pressure is passed from the pressure line 193, through the pipe 202 into the end chamber 201 of the control valve 199 to move the valve toward the left (Fig. 3).

The control lever 230 is provided with a downwardly extending integral arm 232 which is connected by a stud to one end of a link 235. The link 235 is connected at its other end to an armature 236 of a pull-type solenoid 237. When the solenoid 237 is energized, it causes the armature 236 and the link 235 to move toward the left into the position illustrated in Fig. 3. This movement shifts the arm 232 and the control lever 230 in a clockwise direction, to stop the cycle at the end of the lapping operation. The solenoid 237 is energized automatically, as will be hereinafter described, to terminate the lapping operation after a predetermined time interval has elapsed.

The arm 232 is provided with an integral downwardly extending projection 240 which is arranged to engage and move an actuating plunger 241 of a normally open limit switch 242 when the control lever 230 is shifted in a counterclockwise direction at the starting of a lapping cycle.

A normally open limit switch 243 is positioned in the path of movement of the arm 63 (Fig. 3). When the lapping arm assembly moves toward an operative position, the arm 63 engages and closes the normally open limit switch 243.

A magnetic starter switch 250 is provided to control the starting and stopping of the forward or normal lapping rotation of the headstock motor 25. A magnetic reverse switch 251 is operatively connected through a motor brake switch 252 (Figs. 1 and 3) to reverse the flow of electric current to the headstock motor 25 and through the motor brake switch 252 rapidly to stop the motor after the desired time interval. A similar magnetic starter switch 253 is provided for controlling the forward or normal relation of the lapping arm reciprocating motor 95 and a magnetic reverse switch 254 is provided to control the reversal of current to the motor 95. A motor brake switch 255 is operatively connected with the motor 95 which serves rapidly to stop the rotation of the motor 95 when it is desired to stop the reciprocating movement of the lapping arm assembly.

In order automatically to control the lapping cycle a pair of electrical time delay relays 260 and 261 are provided. These relays are shown diagrammatically in Fig. 3 and may be of any standard commercial instantaneous reset timers which are in common use in the machine tool field. As illustrated in Fig. 3 a relay known commercially as "Microflex" Instantaneous Reset Timer, manufactured by the Eagle Signal Corporation may be employed. The electric timer 260 is so connected in the electric system that when the control lever 230 is shifted in a counterclockwise direction to start a lapping cycle, the valve stem 196 is moved downwardly so as to admit fluid under pressure to the pipe 197 to cause the valve stem **200** to move toward the left (Fig. 3) at the same time the normally open limit switch **242** is closed. During the initial shifting movement of the valve stem **200**, fluid is admitted through the pipe **214** into the cylinder chamber **215** to actuate the footstock center **45** and move in into an operative position in supporting engagement with the work supporting arbor **36** after which fluid under pressure is admitted to the cylinder chamber **210** of the cylinder **68** to cause a movement of the lapping arm assembly toward an operative position. During the movement of the lapping arm assembly, the switch **243** is closed. The switch **243** is connected in series with the limit switch **242** so that when both of these switches are closed, the circuit is completed and the electric starter switch **250** operates to start the headstock motor **25** and at the same time sets the time relay **260** in motion to energize the starter switch **253** and start the motor **95** to reciprocate the lapping arms during a lapping operation.

The magnetic starter switch **253** is actuated to start the electrical motor **145** which in turn serves in a manner above described to continuously feed abrasive paper during a lapping operation. The electrical motor **145** is connected with the time relay **260** so that after a predetermined initial lapping operation has taken place, the relay **260** operates to stop the motor **95** to stop the lapping arm reciprocation and also to stop the motor **145** so as to stop the continuous feed of the abrasive lapping paper for a final lapping operation.

Operation

The operation of this improved lapping machine will be readily apparent from the foregoing disclosure. Two sets of work pieces to be lapped are clamped in position on the work supporting arbor **36** which is placed in a rotating position on a pair of spaced work arbor supporting cradles after which the work arbor **24** is rolled into position with its axis in alignment with the axis of the headstock spindle **24** and the footstock center **45**. The motor driven fluid pump **190** is then set in motion. When it is desired to start a lapping cycle, the control lever **230** is shifted manually in a counterclockwise direction (Figs. 1 and 3) to shift the start and stop valve **194** to a starting or downward position which admits fluid under pressure through the pipe **197** to cause the control valve **199** to move toward the left to initiate a lapping cycle. The shifting of the control valve **199** toward the left serves first to admit fluid through the pipe **214** to actuate the footstock center **45** so as to move it into operative supporting engagement with the work arbor **36** after which fluid is admitted through the pipe **209** to the cylinder **68** to move the lapping arm assembly to an operative position. Continued movement of the valve **199** toward the left serves to admit fluid under pressure through the pipe **185** automatically to actuate the clamping mechanism to clamp the lapping arm assembly in an operative position.

The movement of the control lever **230** to a starting position serves to close the normally open limit switch **242** and the movement of the lapping arm assembly serves to close the normally open limit switch **243** which closes a series circuit to start the work drive motor **25** and at the same time sets the time relay **260** in motion and to start the motor **95** to impart a reciprocating movement to the pair of slides **90** and **91**. This movement imparts a simultaneous reciprocatory movement in opposite directions to the slides **90** and **91**, so as to impart a relative reciprocating movement to the lapping arms. At the same time the motor **95** is started, the motor **145** is started to impart a continuous feeding movement to the abrasive lapping paper. The lapping operation proceeds for a predetermined time interval as governed by the time relay **260**. After a predetermined time interval has elapsed, the relay **260** serves to simultaneously stop the motors **95** and **145** thus stopping the reciprocation of the lapping arms and at the same time stopping the continuous feed of the abrasive lapping paper after a predetermined initial lapping has been completed. The lapping operation continues for a final or finish lapping operation. When the relay **260** is actuated after the initial lapping operation has been completed, it serves to set in motion the second time delay relay **261** which governs the extent of the final or finish lapping operation. After a predetermined final or finish lapping operation during which time the abrasive lapping paper is held stationary and the lapping arms are not reciprocated, the time relay **261** operates to energize the solenoid **237** to shift the control lever **230** in a counterclockwise direction into the position illustrated in Fig. 3 to initiate a movement of the electric and hydraulic controls. The start and stop valve **194** is moved upwardly into the position shown in Fig. 3 which serves to admit fluid under pressure through pipe **197** into the end chamber **198** so as to move the valve stem **200** toward the right into the position illustrated in Fig. 3 during which time fluid under pressure is admitted through the pipe **186** to release the hydraulic clamping mechanism after which the lapping arm assembly is moved to an inoperative position. Movement of the lapping arm assembly to an inoperative position serves to open the limit switch **243** as previously described. The fluid under pressure is then admitted to the footstock cylinder chamber **217** to withdraw the footstock center **45**, and the work arbor **36** may then be removed from the machine and the next work arbor placed in position for the necessary lapping operation.

It will be readily apparent from the foregoing disclosure that the predetermined or initial lapping operation may be automatically controlled by the setting of the time relay **260** and the duration of the final or finish lapping operation may be readily controlled by manipulation of the time relay **261**, thus providing a readily controlled automatic cycle of operation, it being only necessary for the operator to initiate the cycle by shifting the main control lever **230** in a counterclockwise direction.

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 matters hereinabove set forth or shown in the accompanying disclosure are to be interpreted as illustrative and not in a limiting sense.

We claim:

1. In a cam lapping machine having a base, a rotatable work support including a headstock and a footstock, a work arbor supported by said headstock and footstock for supporting a cam to be lapped, a movably mounted support on said base, a slidably mounted cam lapping arm on said support, a lapping element on said arm, a

rotatable follower roller on said arm, and a master cam on said arbor adjacent to the cam to be lapped which cooperates with said follower to impart a controlled sliding movement to said lapping arm and said element to maintain said lapping element continuously in lapping engagement with the face of said cam during a lapping operation.

2. In a cam lapping machine having a rotatable work support including a headstock and a footstock, a work arbor supported thereby for supporting a cam to be lapped, a slidable cam lapping arm, a yieldably mounted nose piece on said arm, a lapping element including a continuous strip of abrasive paper on said arm, a rotatable follower roller on said arm, and a master cam supported on said work arbor adjacent to said cam to be lapped to impart a controlled sliding movement to said arm during a lapping operation.

3. In a cam lapping machine having a base, a rotatable work support for supporting and rotating a cam to be lapped, a movable support on said base, a movable cam lapping arm on said support having a lapping element, a follower on said arm, a master cam for controlling the movement of said follower and arm, means to move said support to and from an operative position, and independent means to clamp said support in an operative position during a lapping operation.

4. In a cam lapping machine having a base, a rotatable work support for supporting and rotating a cam to be lapped, a movable support on said base, a slidably mounted cam lapping arm on said support, a lapping element on said arm, a follower on said arm, a master cam to impart a controlled movement to said arm during a lapping operation, means including a piston and cylinder to move said support and lapping arm to and from an operative position, and means including a fluid pressure actuated clamp to clamp said support in an operative position.

5. In a cam lapping machine having a base, a rotatable work support for supporting and rotating a cam to be lapped, a pivotally mounted frame supported on said base, a slidably mounted lapping arm on said frame, a lapping element on said arm, a follower on said arm, a master cam which is arranged to impart a controlled movement to said arm during a lapping operation, means to swing said frame to and from an operative position, and independent means to clamp said frame in an operative position relative to said base during a lapping operation.

6. In a cam lapping machine having a base, a rotatable work support for supporting and rotating a cam to be lapped, a pivotally mounted frame on said base, a slidably mounted lapping arm on said frame, a lapping element on said arm, a follower on said arm, a master cam to impart a controlled movement through said follower to said arm during a lapping operation, means including a piston and cylinder to swing said frame to and from an operative position, and means including a piston and cylinder actuated clamp to lock said frame in an operative position during a lapping operation.

7. In a cam lapping machine having a base, a rotatable work support for supporting and rotating a cam to be lapped, a pivotally mounted frame, a slidably mounted lapping arm on said frame, a lapping element on said arm, a follower on said arm, a master cam to impart a controlled movement through said follower to said arm during a lapping operation, means including a piston and cylinder to move said frame and lapping arm to and from an operative position, a piston and cylinder actuated clamping mechanism to lock said frame in an operative position during a lapping operation, and a control valve which is arranged successively to admit fluid to said cylinder for moving said frame and thereafter to said clamp actuating cylinder.

8. In a cam lapping machine having a base, a rotatable work support including a headstock and footstock for rotatably supporting a plurality of cams to be lapped, a pivotally mounted frame, a plurality of slidably mounted lapping arms on said frame, a lapping element on each of said arms, a follower on each of said arms, a master cam to impart a controlled movement through said follower to said arm, a clamping mechanism to clamp the frame in an operative position, means including a piston and cylinder to actuate said footstock, means including a piston and cylinder to move said frame and lapping arms to and from an operative position, and means including a piston and cylinder to actuate said clamp.

9. In a cam lapping machine having a base, a rotatable work support including a headstock and footstock for rotatably supporting a plurality of cams to be lapped, a pivotally mounted frame, a plurality of slidably mounted lapping arms on said frame, a lapping element on each of said arms, a follower on each of said arms, a master cam to impart a controlled movement through said follower to said arm, a clamping mechanism to clamp the frame in an operative position, means including a piston and cylinder to actuate said footstock, means including a piston and cylinder to move said frame and lapping arms to and from an operative position, means including a piston and cylinder to actuate said clamp, and a control valve which is arranged successively to admit fluid under pressure to said footstock cylinder, said frame cylinder, and said clamping cylinder.

10. In a cam lapping machine having a base, a rotatable work support including a headstock and footstock for rotatably supporting a plurality of cams to be lapped, a pivotally mounted frame, a plurality of slidably mounted lapping arms on said frame, a lapping element on each of said arms, a follower on each of said arms, a master cam to impart a controlled movement through said follower to said arm, a clamping mechanism to clamp the frame in an operative position, means including a piston and cylinder to actuate said footstock, means including a piston and cylinder to move said frame and lapping arms to and from an operative position, means including a piston and cylinder to actuate said clamp, a control valve which is arranged successively to admit fluid under pressure to said footstock cylinder, said frame cylinder, and said clamping cylinder, and a manually operated start and stop valve to control the actuation of said control valve to initiate a lapping operation.

11. In a cam lapping machine having a base, a rotatable work support including a headstock and footstock for rotatably supporting a plurality of cams to be lapped, a pivotally mounted frame, a plurality of slidably mounted lapping arms on said frame, a lapping element on each of said arms, a follower on each of said arms, a master cam to impart a controlled movement through said follower to said arm, a clamping mechanism to clamp the frame in an operative position, means including a piston and cylinder to actuate

said footstock, means including a piston and cylinder to move said frame and lapping arms to and from an operative position, means including a piston and cylinder to actuate said clamp, a control valve which is arranged successively to admit fluid under pressure to said footstock cylinder, said frame cylinder, and said clamping cylinder, a start and stop valve to control the admission of fluid to the end chambers in said control valve, manually operable means to shift said start and stop valve to initiate a lapping cycle, and an automatically actuated mechanism to shift said start and stop valve after a predetermined lapping operation has been completed to terminate the lapping cycle.

HERBERT S. INDGE.
CHARLES W. LUND.