

July 11, 1939.

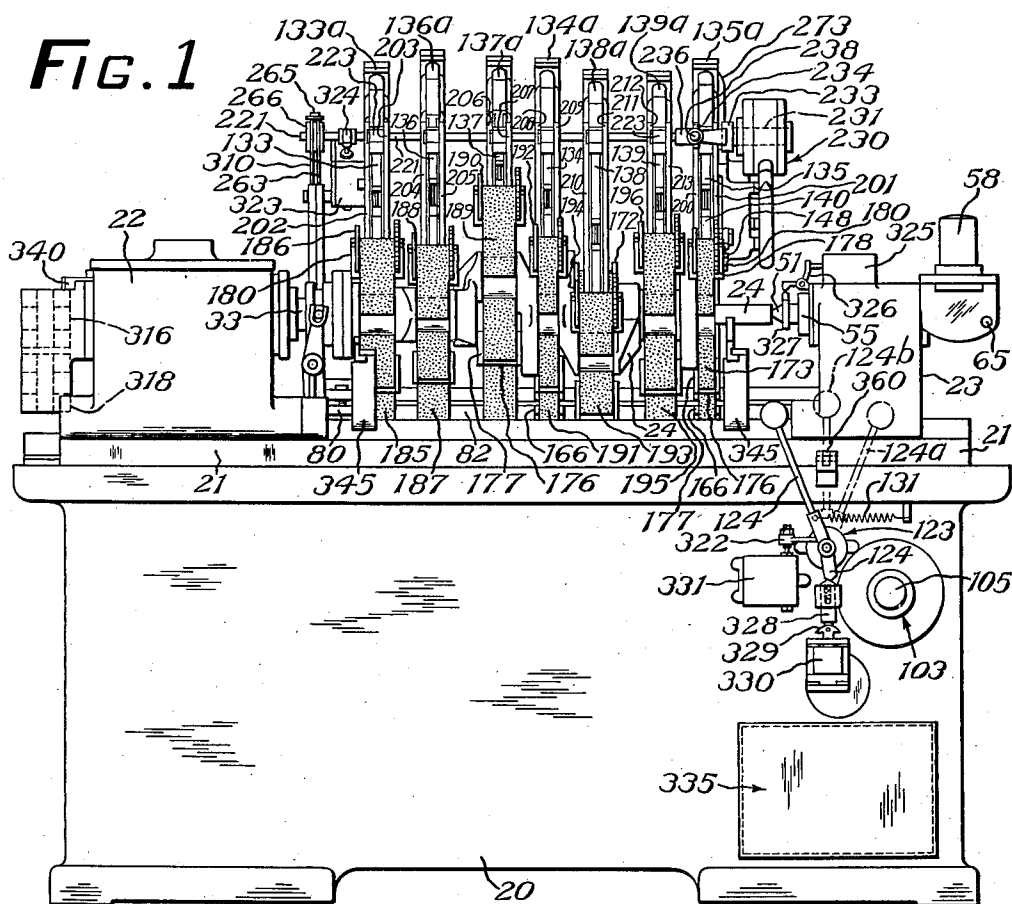
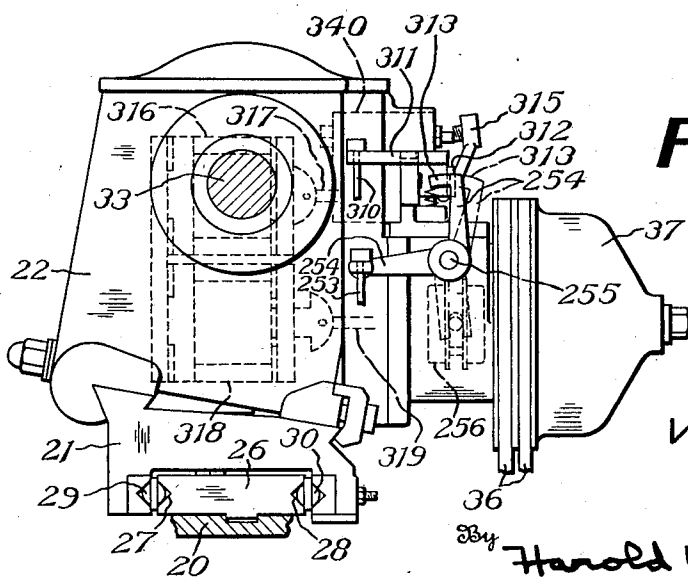
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2,166,085

LAPPING MACHINE

Filed Nov. 3, 1938

5 Sheets-Sheet 1



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LAPPING MACHINE

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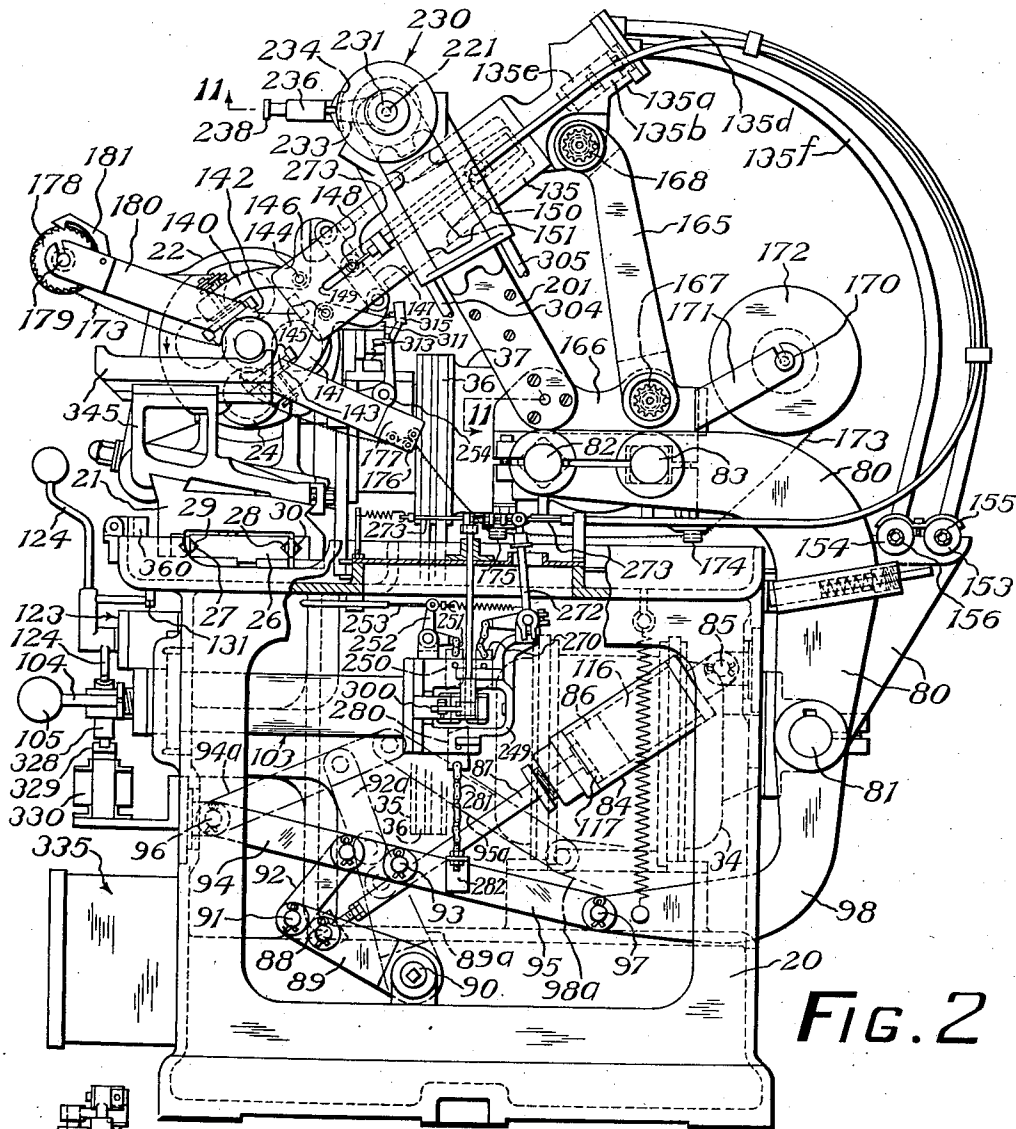


FIG. 2

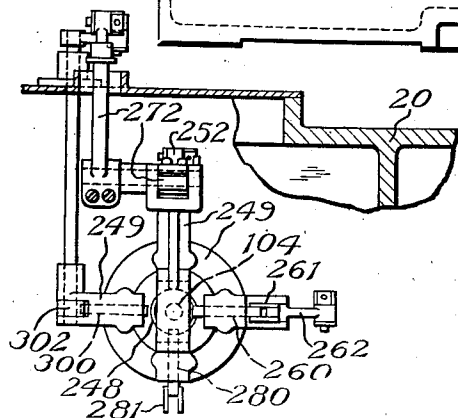


FIG. 9

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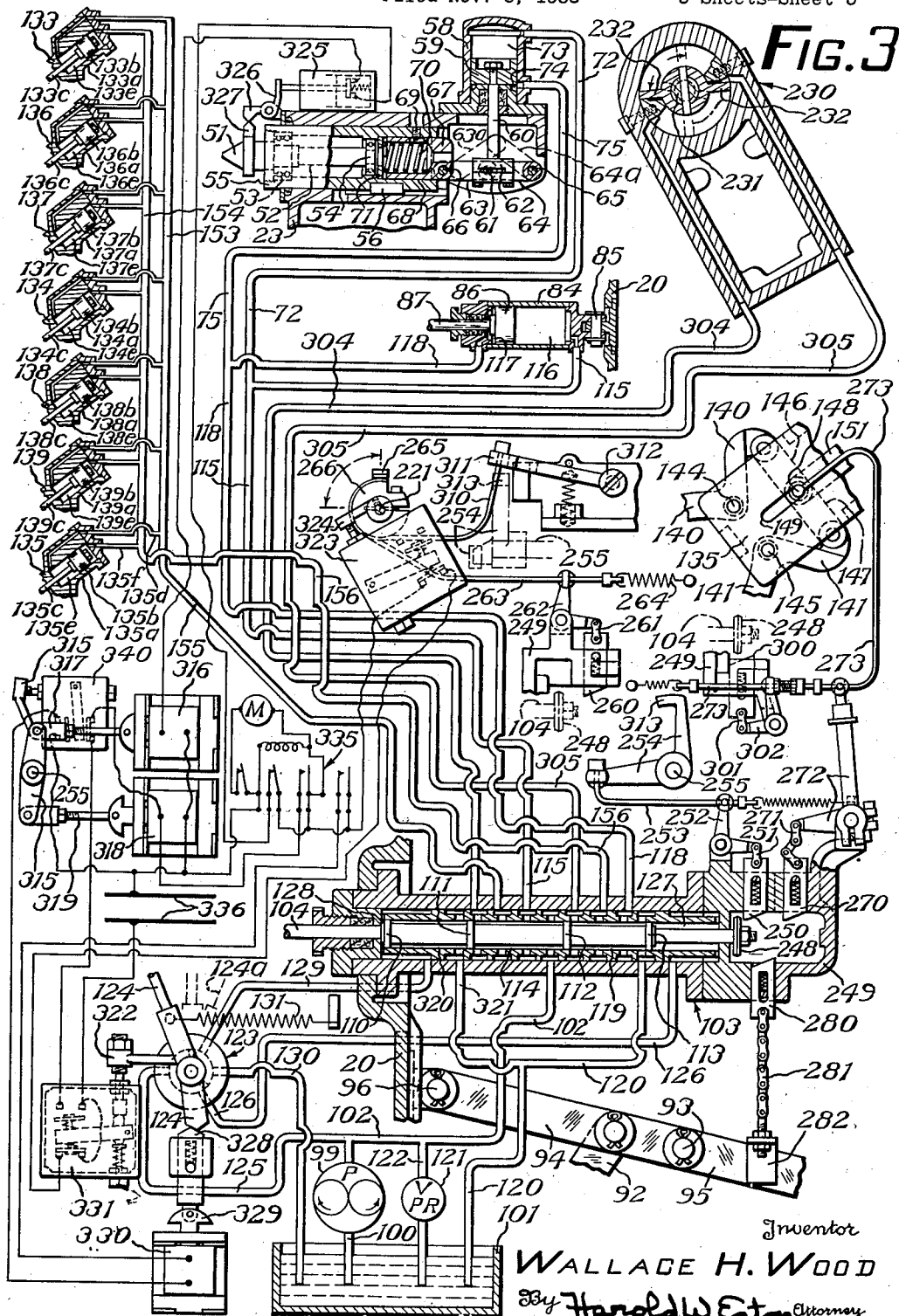
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LAPPING MACHINE

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LAPPING MACHINE

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UNITED STATES PATENT OFFICE

2,166,085

LAPPING MACHINE

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9 Claims. (Cl. 51—73)

This invention relates to abrading machines, and more particularly to a lapping machine for lapping crankshafts and the like.

One object of the invention is to provide a simple and thoroughly practical lapping machine for simultaneously lapping or polishing a plurality of crankpins and main bearings on a crankshaft or the cams and main bearings on a camshaft. A further object of the invention is to provide a lapping machine in which all of the crankpins and main bearings may be simultaneously lapped. A further object of the invention is to provide a crankshaft lapping machine for simultaneously lapping the crankpins and bearings of a crankshaft, in which a plurality of lapping arms are hydraulically operated.

Another object of the invention is to provide a lapping machine for lapping work pieces such as crankshafts, camshafts and the like, in which the footstock, the lapping arms, the lapping arm clamping mechanism, the lapping arm carrier, and the footstock are all hydraulically operated by independent fluid motors. A further object of the invention is to provide such a lapping machine in which a common control valve controls the admission of fluid to the footstock cylinder, the lapping arm cylinders, the lapping arm clamping cylinder, and the lapping arm carrier cylinder.

A further object of the invention is to provide a hydraulically operated lapping machine in which all of the hydraulically operated mechanisms are interlocked by the control valve and a plurality of automatically actuated latches or stops are provided so as definitely to interlock the various mechanisms of the machine. Another object of the invention is to provide an electrical interlock between the main control lever, the footstock actuating mechanism, and the lapping arm clamping mechanism so that the headstock cannot be set in motion until the footstock center has moved into operative supporting engagement with the work piece to be lapped and the clamping mechanism has released the lapping arms. 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 crankshaft lapping machine;

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

Fig. 3 is a diagrammatic illustration of the hydraulic actuating mechanism and piping together with the control valve and the interlocking stop or latch mechanism therefor;

Fig. 4 is a horizontal sectional view through the hydraulic control valve, showing the valve in its second position during its rearward movement;

Fig. 5 is a vertical sectional view through the control valve, showing the valve in its third position on its rearward movement;

Fig. 6 is a similar vertical sectional view, showing the control valve in its rearward or right-hand position;

Fig. 7 is a similar vertical sectional view, showing the control valve in its second position during its forward movement;

Fig. 8 is a similar horizontal sectional view, showing the control valve in its third position during its forward movement;

Fig. 9 is a fragmentary sectional view showing the rear end of the control valve and latch mechanism in elevation;

Fig. 10 is a right-hand end elevation of the headstock mechanism, on an enlarged scale;

Fig. 11 is a fragmentary sectional view taken approximately on the line 11—11 of Fig. 2, showing the lapping arm clamping mechanism;

Fig. 12 is a fragmentary end elevation of a crank lapping arm and its supporting and clamping mechanism; and

Fig. 13 is a fragmentary cross-sectional view, on an enlarged scale, taken approximately on the line 13—13 of Fig. 11.

A crankshaft lapping machine has been illustrated in the drawings comprising a base 20 which supports a longitudinally reciprocable work supporting table 21. Table ways are provided between the base 20 and the table 21 which in the preferred form are of an antifriction type. The base 20 is provided with a plate 26 which is fixed to the base 20 and is provided at its edge portions with grooves 27 and 28 which serve as inner raceways for a pair of spaced rows of anti-friction balls 29 and 30, respectively. A cage is provided between the races to space the balls 29 and 30 longitudinally, as desired. This construction forms an anti-friction way whereby the table 21 together with a headstock 22 and a

footstock 23 may be readily reciprocated during the lapping operation.

Headstock

5 The headstock 22 is provided with a rotatable spindle 33 which is supported in bearings (not shown). The headstock spindle 33 may be rotated from any suitable source of power, such as an overhead belt drive, or a self-contained
10 electric motor. In the preferred construction, an electric motor 34 is mounted in the base 20 of the machine. The motor 34 is provided with a driving pulley 35 which is connected by multiple V-belts 36 with a pulley 37 on the headstock 22.
15 The headstock construction has not been illustrated in detail in the present application since this headstock is not considered to be a part of the present invention and, furthermore, is substantially identical with that shown in the prior
20 United States Patent No. 2,092,734 dated September 7, 1937, except that it does not require the built-in cycle counting mechanism. Reference may be had to the above-mentioned patent for details of disclosure not found herein.

Table reciprocation

25 In the lapping of crankpins and main bearings of an automotive crankshaft or the cams and main bearings of an automotive camshaft, it is desirable to provide a relative reciprocatory movement between the crankshaft or camshaft being lapped and the lapping or abrading element to prevent production of abrasive grain markings on the pins and bearings of the crankshaft. In
30 the present case, the work table 21 is arranged for a longitudinal reciprocatory movement which is preferably accomplished by a translation of the rotary motion of the headstock spindle 33 into a reciprocatory movement of the table 21.
35 The specific mechanism for reciprocating the table 21 has not been illustrated in the present case, since this mechanism is identical with that shown in the prior United States Patent No. 2,092,734 dated September 7, 1937, to which reference may be had for details of the table reciprocating mechanism not found herein.

Footstock

40 The other end of the crankshaft 24 is supported by the footstock 23 which is provided with a footstock center 51. The center 51 is carried by a rotatable spindle 52 which is journaled in bearings 53 and 54 within a hollow slidably mounted sleeve 55. The sleeve 55 is slidably keyed by means of a key 56 within an aperture in the
45 footstock frame.

A fluid pressure actuated mechanism is provided for moving the footstock center 51 rapidly to and from an operative position to support one end of a crankshaft 24 within the machine. This mechanism comprises a fluid pressure cylinder 58 having a slidably mounted piston 59 contained therein. The piston 59 is connected to one end of a piston rod 60 which is connected to a pin 61. The central portion of the pin 61 is slotted off on opposite sides so as to slide within an elongated slot 62 formed in the lower enlarged end of the piston rod 60. The pin 61 serves as a central pivotal connection between a pair of
50 toggle levers 63 and 64. The toggle lever 64 is connected to the footstock frame by means of a stud 65. The other end of the toggle lever 63 is connected by a stud 66 with a slidably mounted hollow sleeve 67 which slides within an aperture 68 within the sleeve 55. The sleeve 67
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is held against rotation by means of a pin 69 which is carried by the sleeve 55 and rides within an elongated slot in the sleeve 55. A spring 70 is contained within the sleeve 67 and is interposed between the end of an aperture of the sleeve 67 and a thrust collar 71.

When fluid under pressure is admitted through a pipe 72 to a cylinder chamber 73, the piston 59 is moved downwardly and the toggle levers 63 and 64 are moved from the dotted line positions 63a and 64a into the full line positions 63 and 64 (Fig. 3) which serves to move the sleeve 67 into the position illustrated. This movement serves to compress the spring 70 and, through the connecting parts, moves the sleeve 55 and footstock center 51 into operative supporting engagement with the end of the crankshaft 24. During this movement, fluid is exhausted from a cylinder chamber 74 through a pipe 75. The admission to and exhaust of fluid from the footstock operating cylinder 58 will be hereinafter described. This footstock is identical with that shown in the prior United States Patent No. 2,117,960 dated May 17, 1938, to which reference may be had for details of disclosure not contained herein.

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 arms 80, only one of which has been illustrated in the drawings (Fig. 2), are mounted on a rock shaft 81 which is supported in bearings on the rear of the machine base 20. The arms 80 are provided with horizontally extending portions which are connected by two spaced bars 82 and 83 which serve as slide bars or ways for supporting a plurality of lapping arms to be hereinafter described.

The lapping arm assembly supported by the arms 80 is arranged so that it may be automatically moved to and from an operating position to facilitate loading of crankshafts into the machine and removing them therefrom after a lapping operation has been completed. In order to move the entire lapping arm assembly to an inoperative position, a fluid pressure mechanism is provided including a fluid pressure cylinder 84 which is pivotally connected by means of a stud 85 within the base 20 of the machine. A piston 86 is slidably mounted within the cylinder 84 and is connected to one end of a piston rod 87. The other end of the piston rod 87 is connected by a stud 88 with an arm 89 pivotally mounted on a shaft 90 supported within the base 20. The other end of the arm 89 is connected by a stud 91 to one end of a link 92. The other end of the link 92 is connected by a stud with a toggle lever 94. The adjacent ends of the toggle lever 94 and a toggle 95 are connected by a stud 93. The toggle lever 94 is connected at its other end by means of a stud 96 with the base 20. The toggle lever 95 is connected by a stud 97 with an arm 98 which is fixedly mounted on the rock shaft 81 and is arranged to rock the shaft 81 together with the arm 80 and all of the crankpin and bearing lapping arms together with their supporting and actuating mechanisms either into or away from an operating position.

The levers 89, 92, 94 and 95, as shown in full lines in Fig. 2, are in a position to hold the arm 98 and the arms 80 together with the entire lapping arm assembly in an operating position. After a lapping operation has been completed, fluid
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under pressure is admitted to the cylinder 84 to cause the piston 86 and piston rod 87 to move toward the right (Fig. 2) to shift the levers 89, 92, 94 and 95 and arm 98 into the dotted line positions 89a, 92a, 94a, 95a and 98a. This movement serves to rock the arms 80 in a clockwise direction (Fig. 2) to move the entire lapping arm assembly to an inoperative position.

Fluid pressure system

A fluid pressure system is provided to control the admission of fluid under pressure to the cylinder 84. A pump 99 within the base 20 of the machine draws fluid through a pipe 100 from a reservoir 101 within the base 20 and passes fluid under pressure through a pipe 102 to a reverse or control valve 103. The valve 103 is of a piston type having a valve stem 104 which is provided at its outer end with a manually operable actuating knob 105.

A plurality of valve pistons 110, 111, 112 and 113 are formed integral with the valve stem 104. Fluid under pressure passing through the pipe 102 passes into a valve chamber 114 located between the valve pistons 111 and 112 and passes out through a pipe 115 into a cylinder chamber 116 within the cylinder 84 to cause the piston 86 to move toward the left (Figs. 2 and 3) to shift the lapping arm support arms 80 in a counter-clockwise direction (Fig. 2) to position the crankpin and bearing lapping arms in an operating position.

During the admission of fluid under pressure to the cylinder chamber 116, fluid is exhausted from a cylinder chamber 117 at the other end of the cylinder 84, through a pipe 118, through a valve chamber 119 located between the valve pistons 112 and 113, and out through a pipe 120 into the reservoir 101. A fluid pressure relief valve 121 is connected by a pipe 122 with the pressure pipe 102 and serves to by-pass excess fluid under pressure within the pipe 102 to the reservoir 101.

The control valve 103 also serves to control the admission of fluid to the footstock actuating cylinder 58. The pipe 72 is connected to the pipe 115 and serves to convey fluid under pressure to the footstock cylinder chamber 73 simultaneously with the passage of fluid under pressure to the cylinder chamber 116 in the cylinder 84. The pipe 75 connects the cylinder chamber 74 of the cylinder 58 with the pipe 118 so that in the position of the control valve 103 (Fig. 3), fluid will exhaust simultaneously from the cylinder chamber 74 in the cylinder 58 and from cylinder chamber 117 in the cylinder 84.

When the control valve 103 is shifted into the position illustrated in Fig. 3, fluid under pressure simultaneously enters both cylinder 58 and the cylinder 84 and due to the fact that less power is required to move the footstock than the lapping arm assembly, the footstock center moves first into an operative position, after which the lapping arm assembly moves to an operative position adjacent to the crankpins and bearings to be lapped.

Main control valve

The control valve 103 is preferably moved in both directions by fluid under pressure which is preferably controlled by a main control valve 123. The main control valve 123 is preferably of a rotary type which is actuated by means of a lever 124 fixedly attached to the valve rotor. Fluid under pressure from the pump 99 passes through a pipe 125 to the main control valve 123 and in

the position illustrated in Fig. 3 passes through a pipe 126 into a valve chamber 127 located in the right-hand end of the control valve 103 so as to shift the valve stem 104 and the pistons formed integrally therewith toward the left (Fig. 3). During this movement of the valve stem 104 toward the left, fluid within an end chamber 128 in the valve 103 exhausts through a pipe 129, through the valve 123, and out through a pipe 130 into the reservoir 101.

When the lever 124 is shifted into position 124a, the passage of fluid is reversed and fluid under pressure is admitted through the pipe 129 into valve chamber 128 to move the control valve stem 104 toward the right (Fig. 3). The movement of the valve stem 104 toward the right or toward the left is restricted by a series of stop plungers to be hereinafter described.

A spring 131 interposed between the lever 124 and a stud fixed on the base of the machine normally tends to hold the lever 124 in position 124a so that the valve is normally held in its rearward position with the parts of the machine positioned for a loading operation.

Lapping arms

In order that all of the crankpins and main bearings on the crankshaft 24 may be simultaneously lapped, a plurality of crankpin and bearing lapping arms are provided which correspond in number with the crankpins and bearings to be lapped. As illustrated, there are three main bearing lapping arms 133, 134 and 135. There are four crank lapping arms 136, 137, 138 and 139. The main bearing and crankpin lapping arms are supported in spaced relationship with each other so as to simultaneously engage and lap the three main bearings and the four crankpins on the crankshaft 24.

The bearing lapping arms and crankpin lapping arms are substantially identical in construction. The bearing lapping arms are stationary while lapping the main bearing surfaces which are concentric with the axis of rotation of the crankshaft 24, whereas the crankpin lapping arms are rocked during the lapping operation due to the fact that they engage a crankpin which revolves about the axis of rotation of the crankshaft 24.

A side elevation of the lapping arm 135 is shown in Figs. 2 and 12. The lapping arm 135 as well as all of the other lapping arms are each provided with a pair of pivotally mounted lap supporting arms 140 and 141 which are provided at their operative ends with partially cylindrical lap supporting blocks 142 and 143, respectively. The arms 140 and 141 are pivotally supported by the studs 144 and 145 on the lapping arm 135. The other ends of the arms 140 and 141 are interconnected by means of a pair of toggle levers 146 and 147 which are connected together at their inner ends by means of a stud 148. The stud 148 slides in an elongated slot 149 in the side plate of the lapping arm 135. When the toggle levers 146 and 147 are in a straight-line position (Fig. 2), the lap supporting members 142 and 143 are maintained in operative engagement to hold an abrasive or lapping element in operative contact with a portion of the crankshaft 24.

The lapping supporting arms 140 and 141 are arranged to be automatically moved into and away from an operative position, and in the preferred construction a hydraulically operated mechanism is provided for actuating the same comprising a fluid pressure cylinder 135a formed

integral with the upper end of the lapping arm 135. A piston 135b is slidably mounted therein and is connected to one end of a piston rod 135c. The other end of the piston rod 135c is connected by a stud 150 with a link 151. The other end of the link 151 is connected to the stud 148 which pivotally connects the adjacent ends of the toggle levers 146 and 147. It will be readily apparent from the foregoing disclosure that when the piston 135b is moved downwardly, that is, toward the left (Fig. 2), the piston rod 135c and the connecting link 151 will be moved also in a downward direction toward the left which serves to unlock the toggle levers 146 and 147 and thereby to rock the lap supporting arms 140 and 141 together with the lap supporting elements 142 and 143 to an inoperative position out of engagement with the crankshaft 24. When fluid under pressure is passed through a flexible pipe 135d into a cylinder chamber 135e, the piston 135b will be moved upwardly to move the toggle levers 146 and 147 into a straight-line position (Figs. 2 and 12) to move the abrasive lapping element into an operative position in engagement with the work piece 24 for a lapping operation. Similarly, when fluid under pressure is admitted through a flexible pipe 135f to cause a downward movement of the piston 135b toward the left (Figs. 2, 3 and 12), the toggle levers 46 and 47 will be unlocked to move the lapping elements to an inoperative position.

It is to be noted in the drawings (Fig. 3) that each of the lapping arms is provided with an independent fluid operated piston and cylinder as well as piston rods which have been designated in the diagram with the same reference numerals as the lapping arm on which it is mounted, the cylinders being designated by the letter a, the pistons by the letter b, the piston rods by the letter c, and cylinder chambers by the letter e.

It is desirable that all of the lapping elements represented by the supporting members 142 and 143 (Fig. 2) be moved into and away from an operating position simultaneously. This is preferably accomplished by providing a pair of longitudinally extending pipes or manifolds 153 and 154 which are fixedly supported on the spaced arms 80 and serve as a common source of fluid under pressure which may be forced either through the flexible pipe 135d to move the lapping element into an operative position, or when the fluid under pressure is reversed, to flow through the flexible pipe 135f simultaneously to move all of the lapping elements to an inoperative position after the lapping operation has been completed. The admission to and exhaust of fluid from the manifolds or pipes 153 and 154 is controlled by the control valve 103. A pipe 155 is connected between the manifold or pipe 153 and the valve chamber 114 and serves in the position of the valve 103 (Fig. 3) to admit fluid under pressure to the manifold or pipe 153, into the cylinder chamber 135e, and simultaneously to all of the other corresponding cylinder chambers in the cylinders on each of the lapping arms to move and hold said lap supporting arms in an operative position for a lapping operation. A pipe 156 is connected between the manifold or pipe 154 and the valve chamber 119 so that in the position of the valve 103 (Fig. 3), fluid may be exhausted from the upper cylinder chambers on each of the lapping arms through the manifold 154 and the valve chamber 119, pipe 120, into the reservoir 101.

Each of the lapping arms 133 to 139 inclusive is pivotally supported. The details of the sup-

port for the lapping arms being identical, only one support has been illustrated in detail. An arm 165 is pivotally mounted on a supporting member 166 which is clamped in adjusted position on the guide rods 82 and 83. The lower end of the arm 165 is pivotally connected to the supporting member 166 by means of a pivotal connection 167. A pivotal connection 168 serves to connect the arm 165 with the lapping arm 135 so that the arm 135 is free to move. All of the lapping arms, both crankpin and main bearing arms, are mounted in the same manner so that when the lapping elements are clamped in lapping engagement with a crankpin and main bearing, the crank lapping arms may follow as the crankpin is revolved to produce the desired lapping action.

A flexible abrasive paper or cloth is preferably utilized as an abrading or lapping medium. Each of the lapping arms is provided with a separate strip of continuous abrasive paper which wraps around the crankpin or main bearing and is held in position thereagainst by the lap supporting members 142 and 143. A rod 170 is supported on the rear of each of the supporting members 166 by means of a bracket 171 and serves as a support for a reel 172 of flexible abrasive paper 173. The abrasive paper passes through guides 174 and 175 supported on the under side of the supporting member 166 and passes through a series of rollers 176 carried by a bracket 177. The abrasive paper above described wraps around a main bearing or crankpin of the crankshaft 24 and is supported by the lap supporting members 142 and 143. The worn or used abrasive paper is wound up on a reel 178 which is supported by a stud 179 carried by a bracket 180 supported on the lap supporting arm 140.

The lap supporting members 142 and 143 are mounted so that they may float or move relative to the arms 140 and 141, so that the lap supporting members 142 and 143 are self-aligning when brought into operative engagement to support the abrasive paper on a crankpin or main bearing for a lapping operation. The brackets 177 and 180 are fixedly mounted to the floating lap supporting members 142 and 143. A holding pawl 181 cooperating with a ratchet wheel on the end of the reel 178 serves to prevent unreeling of the worn abrasive paper wound up on the reel 178 when the lap supporting arms are moved to and from an operating position. As illustrated in the drawings, the abrasive paper is fed manually when desired by the operator by manually turning the reel 178. Only one of the reels 178 and the associated parts to guide the abrasive paper through to the reel 178 have been illustrated in detail. Each lapping arm is provided with similar equipment supported on a separate supporting member 166. The abrasive paper and wind-up reels for each of the lapping arms are illustrated in the front elevation of the machine, as shown in Fig. 1.

The lapping arm 133 is supplied with a strip of abrasive paper 185 which is wound up on a reel 186. The lapping arm 136 is provided with a strip of abrasive paper 187 and the used portion thereof is wound up on a reel 188. The lapping arm 137 is supplied with a strip of abrasive paper 189, the used portion of which is wound up on a reel 190. The lapping arm 134 is supplied with a strip of abrasive paper 191, the used portion of which is wound up on a reel 192. The arm 138 is supplied with a strip of abrasive paper 193, the used portion of which is wound up on

a reel 194. The lapping arm 139 is supplied with a strip of flexible abrasive paper 195, the used portion of which is wound up on a reel 196. Inasmuch as the abrasive paper supporting reels and the guiding means are identical for each of the lapping arms, only one of these mechanisms has been completely illustrated, as shown in Fig. 2.

It is desirable to provide a guiding means for guiding the lapping arms during their swinging movement as they follow the revolving crankpin and to provide a clamping mechanism to clamp all of the lapping arms in their indexed position relative to the supports 166 before the lap supporting members 142 and 143 are released from operative position and the lapping arm assembly swung to an inoperative position to facilitate loading of the machine. It is desirable to provide such a clamping device so that when the arms 80 are moved to an operating position after a new crankshaft has been loaded into the machine, all of the lapping arms will be in the proper indexed position so that the lap supporting members 142 and 143 may be automatically brought into engagement simultaneously with the crankpins and bearings of the crankshaft 24.

In order that the lapping elements may be guided in their swinging movement and held against lateral movement during the reciprocation or oscillation of the crankshaft 24 during the lapping operation, a pair of parallel guiding plates 200 and 201 are fixedly mounted on the supporting bracket 166 and are spaced apart by a distance equal to the thickness of the lapping arm 135. The lapping arm 135 is guided thereby and is held against lateral movement by the guiding plates 200 and 201. The lapping arm 133 is similarly guided by the guiding plates 202 and 203. The lapping arm 136 is guided by guiding plates 204 and 205. The lapping arm 137 is guided by guiding plates 206 and 207. The lapping arm 134 is guided by guide plates 208 and 209. The lapping arm 138 is guided by guide plates 210 and 211, and the lapping arm 139 is guided by guide plates 212 and 213.

Lap arm—clamp device

In order to provide means for simultaneously clamping all of the crankpin and bearing lapping arms in their respective index positions, the guide plates 200, 202, 204, 206, 208, 210 and 212 are each provided with a groove or guideway 214 which supports a slidably mounted member 215 having cam surface depressions 216 formed therein. The guide plate 200 is provided with a pair of cams 217 and 218 which engage the cam shaped depressions 216 formed in the slidably mounted member 215. It will be readily apparent that if the slide 215 is moved upwardly (Fig. 11) relative to the guiding plate 200, the cam depressions 216 engaging the fixed cams 217 and 218 will cause the slide member 215 to move toward the right (Fig. 11) and thereby bind or clamp the lapping arm 135 in a fixed position relative to the guide plates 200 and 201. Each of the lapping arms 133 to 139 inclusive is provided with an identical clamping means, consequently only one of these clamps has been illustrated in detail. The guide plates 202, 204, 206, 208, 210 and 212 are each provided with a clamping slide 202a, 204a, 206a, 208a, 210a and 212a, respectively.

In order simultaneously to clamp all of the lapping arms, a mechanism is provided for simultaneously actuating the clamping slides 215, 202a, 204a, 206a, 208a, 210a and 212a. As illustrated in

the drawings, a shaft 221 is rotatably supported in apertures in the guiding plates 200 to 212 inclusive. Each of the clamping slides is provided with an elongated slot 222 (Fig. 13). The shaft 221 carries an eccentric 223 which rides within the elongated slot 222. When the shaft 221 is rotated, the eccentric 223 rotating within the elongated slot 222 causes the clamping slide 215 to move relative to the guiding plates 200 and 201. The shaft 221 is provided with a plurality of eccentric members corresponding to the eccentric 223, each of which is arranged to engage elongated slots in the respective clamping slides 202a, 204a, 206a, 208a, 210a and 212a.

Clamp actuating motor

A vane type fluid pressure motor 230 is provided for rocking the shaft 221 to clamp and release the lapping arms. The motor 230 is provided with a rotor shaft 231 which supports a rotary vane 232. The rotor shaft 231 projects from the motor casing toward the left (Fig. 11). An arm 233 is supported on one end of the rotor shaft 231. The arm 233 is provided with an enlarged head 234 having a notch 235 formed in the outer end thereof. A lever 236 is fixedly mounted on the shaft 221 and is provided with a spring-pressed plunger 237 which is arranged to engage the notch 235 to lock the lever 236 to the lever 232 so that the rotation of the vane 232 of the motor 230 will be transmitted to rotate the shaft 221 to clamp or release the lapping arms. The plunger 237 is connected with a knob 238 by means of which the plunger 237 may be withdrawn from the notch 235 so that the clamping mechanism may be operated manually, if desired.

In order to attain one object of the invention, it is desirable to provide suitable interlocks so that the various mechanisms of the machine will operate in a predetermined sequence. When a crankshaft has been loaded into the machine, the control lever 124 is moved in a counterclockwise direction (Fig. 3) to shift the valve 123 so as to admit fluid under pressure through the pipe 126 into the valve chamber 127 to shift the control valve 103 and start the cycle of operation. It is desirable that the various mechanisms should operate in the following sequence:

- (a) Footstock center 51 moves in to grip the work.
- (b) Arms 80 which support the crankpin and bearing lapping arms swing forward into an operating position.
- (c) Jaws close onto work.
- (d) Lapping arms unclamped.
- (e) Headstock starts rotation, allowing work to rotate a predetermined number of rotations.
- (f) Headstock stops rotation.
- (g) Lapping arms are clamped in an indexed position.
- (h) Jaws open.
- (i) Arms 80 swing back to inoperative position.
- (j) Footstock center 51 moves out of engagement with work to release the same, after which the crankshaft may be unloaded from the machine.

Interlocks

The ports in the valve 103 are so arranged that fluid under pressure will be admitted to the various hydraulic cylinders in the sequence above enumerated. It is, however, desirable that the various mechanisms have sufficient time to function before the next mechanism operates. It is, therefore, desirable to provide an interlocking of

the various mechanisms which may comprise a series of stops which serve to limit the movement of the control valve when it is moved in either direction. These stops are interconnected with the various mechanisms so that after a mechanism has performed its function, the valve stop will be automatically withdrawn, thereby permitting a further movement of the control valve 103.

10 A stop collar 248 is fixedly mounted on the rear end of the valve stem 104. The collar 248 is arranged to slide within an aperture within a casing 249 fixedly mounted on the rear end of the casing of the valve 103. The casing 249 serves as a support for a plurality of spring-pressed stops which are arranged intermittently to stop the movement of the valve stem 104 when it is moved either towards the rear after a lapping operation has been completed or when the valve is moved forward after a new crankshaft has been loaded into the machine to start a lapping operation. As shown in Fig. 3, the valve 103 together with the other mechanisms of the machine are shown in the position during the lapping operation.

When the valve stem 104 is in the forward position (Fig. 3), a stop pawl 250 serves to prevent shifting the valve toward the rear to stop the lapping operation. The stop plunger 250 is connected by a link 251 to one arm of a bell crank lever 252 which in turn is connected by a flexible cable commonly known as a Bowden wire 253 with one arm of a bell crank lever 254. The bell crank lever 254 is mounted on the outer end of a clutch operating shaft 255 on the headstock 22 which is connected to move a clutch 256 into or out of engagement to start the headstock rotation. As shown in the drawings (Figs. 3 and 10), the headstock clutch is engaged and the crankshaft is being lapped. This lapping operation continues until a solenoid controlled by an electrical time delay relay to be hereinafter described disengages the headstock clutch and automatically stops the headstock after the lapping operation has continued for a predetermined time interval. When the clutch 256 is disengaged to stop the headstock rotation, the shaft 255 and bell crank 254 are rocked in a clockwise direction and this movement serves to pull on the flexible cable 253 to rock the bell crank 252 in a counterclockwise direction and thereby automatically withdraw the stop plunger 250 from the path of the stop collar 248. During the lapping operation when the headstock is running, the stop plunger 250 prevents accidental shifting of the valve towards the rear and holds it locked in a forward operating position.

The valve stem 104 may then be shifted until the stop collar 248 engages a stop plunger 260 which is arranged in a manner to be hereinafter described to prevent further rearward movement of the valve until the lapping arms are clamped in position. The spring-pressed stop plunger 260 is connected by a link 261 with one arm of a bell crank lever 262, the other arm of which is connected to a flexible cable or Bowden wire 263. A spring 264 normally tends to move the bell crank in a clockwise direction. The Bowden wire or flexible cable 263 is wound partially around the periphery of a disk 266 which is mounted on the end of the shaft 221 and is connected by means of a screw 265 with the periphery of the disk 266 (Fig. 11). The valve stem 104 cannot be moved further towards its rearward position until fluid under pressure admitted

through a pipe 305 actuates the clamping motor 230 and thereby clamps the lapping arms in an indexed position. The motor 230 rotates in a clockwise direction (Fig. 3) to clamp the lapping arms and this movement also rotates the shaft 221 and the disk 266 also in a clockwise direction which serves to pull the flexible cable or Bowden wire 263 toward the left (Fig. 3), thus rocking the bell crank lever 262 in a counterclockwise direction which serves automatically to withdraw the stop plunger 260 out of the path of the stop collar 248.

The valve stem 104 may then be moved rearwardly until it is again stopped by the stop collar 248 engaging the stop plunger 270. The plunger 270 is connected by a link chain 271 with one arm of a bell crank lever 272, the other arm of which is connected to a flexible cable or Bowden wire 273. The other end of the Bowden wire or cable 273 is connected to the stud 148 which connects the toggle levers 146 and 147 with the hydraulic actuating mechanism. The valve stem 104 cannot be moved further to the rear until fluid under pressure admitted through the pipe 156 into the manifold or pipe 154 causes a downward movement of all of the pistons 133b, 136b, 137b, 134b, 138b, 139b and 135b to actuate the toggle levers and open the lap supporting arms or jaws. The downward movement of all of these pistons serves through the Bowden wire 273 to rock the bell crank lever 272 in a clockwise direction (Fig. 3) which in turn, through the link chain 271, automatically withdraws the stop plunger 270 from the path of the stop collar 248. After the plunger 270 has been withdrawn from the path of the stop collar 248, the valve stem 104 is shifted automatically into its extreme rearward position, namely, that shown in Fig. 6, so as to admit fluid under pressure through the pipe 118 into the cylinder chamber 117 of the cylinder 84 to rock the arms 80 so as to simultaneously withdraw the entire lapping arm assembly to an inoperative position. At the same time the arms 80 withdraw the lapping arm assembly to an inoperative position, fluid under pressure is admitted through the pipe 76 to actuate the piston 59 and withdraw the footstock center 51. In this position of the parts, the crankshaft which has just been lapped may be removed from the machine.

After a new shaft has been inserted in the machine, the valve stem 104 is moved toward the left (Fig. 7). The valve stem 104 can be moved until the stop collar 248 engages a stop plunger 280 which prevents further forward movement of the valve. This forward movement of the valve is sufficient to uncover the port and admit fluid under pressure through the pipe 116 into the cylinder chamber 116 of the cylinder 84 to cause the arms 80 supporting the lapping arm assembly to move to an operating position. The stop plunger 280 is connected by a link chain 281 with a bracket 282 which is fixed to the lever 95. When the lever 95 is moved into the position illustrated in Fig. 2, the stop plunger 280 is moved downwardly (Fig. 3), thus permitting a further automatic forward movement of the valve stem 104 until the stop collar 248 engages a stop plunger 300. The stop plunger 300 is connected by a link 301 with a bell crank lever 302 which is also connected to the Bowden wire or flexible cable 273.

The movement of the valve stop collar 248 into engagement with the stop plunger 300 serves to uncover a port so as to admit fluid under pres-

sure through the pipe 155 to manifold or pipe 153 and thereby admit fluid under pressure to the lapping arm cylinders to close the lap supporting arms or jaws into operating engagement with the work. This closing movement causes the pin 148 to move upwardly (Fig. 3) into the position illustrated therein which serves through the Bowden wire 273 to rock the bell crank lever 302 in a counterclockwise direction automatically to withdraw the stop plunger 308 out of the path of the stop collar 248, thus permitting the valve stem 104 automatically to be moved further in a forward direction, that is, toward the left (Fig. 3) until it uncovers a port to admit fluid under pressure through the pipe 304 to actuate the lapping arm clamping motor 230 to unclamp the lapping arms. This movement rotates the shaft 221 and the disk 266 in a counterclockwise direction which serves through a Bowden wire or flexible cable 310 to rock a lever 311 which is pivotally mounted on a stud 312 on the headstock in a clockwise direction into the position illustrated in Fig. 3, thus shifting the lever 311 out of the path of a projection 313 on the bell crank lever 254, which renders the headstock operative. In this position of the parts, the headstock clutch 256 may then be automatically engaged to start the rotation of the headstock and the crankshaft 24 to be lapped. The lapping operation continues until an electrical time delay relay automatically disengages the headstock clutch after a predetermined time interval and again stops the rotation thereof, after which the cycle of operation of the valve and its interlocking plungers is again repeated.

After the headstock has been stopped by shifting of the clutch, the bell crank lever 354 rocks in a clockwise direction (Fig. 10) and when the hydraulic motor 230 is actuated to rotate the shaft 221 and the disk 266 to clamp all of the lapping arms in an indexed position, the Bowden wire or flexible cable 310 is pulled to rock the lever 311 in a counterclockwise direction, that is, downwardly, as shown in Fig. 3, until a portion of the lever 311 lies in the path of the end 313 of the bell crank lever 254 so as to prevent starting the headstock rotation when the lapping arms are in a clamped position. It will thus be seen that by providing a plurality of stop plungers to cause a restricted intermittent movement of the valve stem 104 both on its rearward and forward movements, all of the various mechanisms of the machine are interlocked so that they must all be actuated in a definite and predetermined sequence.

When the valve 103 is in the position illustrated in Fig. 3, fluid under pressure entering through the pipe 102 enters a valve chamber 114 between the valve pistons 111 and 112 and may pass through the pipes 115, 155 and 304 to the various mechanisms of the machine. In this position of the valve, fluid may exhaust from the other side of the various fluid cylinders through the pipes 118, 156 and 305, into the valve chamber 119 located between the valve pistons 112 and 113, and pass out through the exhaust pipe 120 to the reservoir 101. Similarly, when the valve is shifted into its other extreme position (Fig. 6), fluid under pressure passing through the pipe 102 enters the valve chamber 114 located between the pistons 111 and 112 and may pass out through pipes 118, 156 and 305. At the same time, fluid may exhaust through the pipes 115, 155 and 304, through a valve chamber 320, and out through an exhaust

pipe 321 which connects with the pipe 120 to return the exhaust fluid to the reservoir 101.

Electrical interlock

In order to attain one object of the invention, it is desirable to provide an electrical interlock between the main control valve, the headstock clutch operating mechanism, the lapping arm clamping mechanism, and the footstock center. It is also desirable to provide an electrical time delay relay connected within said electrical circuit whereby the lapping operation may proceed for a predetermined time interval, after which the headstock clutch may be automatically disengaged and the main control valve 123 automatically shifted to move the various mechanisms of the machine to an inoperative or loading position.

The headstock clutch 256 is arranged to be actuated by means of a rock shaft 255 (Figs. 3 and 10). A rock arm 315 is fixedly mounted on one end of the rock shaft 255. An electrical solenoid 316 is connected by a link 317 with the upper end of the rock arm 315 (Fig. 3) and serves to rock the shaft 255 in a clockwise direction (Fig. 3) to engage the headstock clutch 256 at the start of a lapping operation.

A solenoid 318 is connected by a link 319 to the lower end of the rock arm 315 and serves when energized to rock the arm 315 and the shaft 255 in a counterclockwise direction (Fig. 3) to disengage the headstock clutch 256 to stop the lapping operation.

A switch 331 is fixedly mounted on the machine base and is actuated by an arm 322 fixedly mounted relative to the valve rotor and the lever 124. The switch 331 is connected in series with a normally open switch 323 which is supported on the upper part of the lapping machine frame and is arranged to be actuated by means of an arm 324 which is fixedly mounted on the clamping mechanism shaft 221. The switch 323, as shown in Fig. 3, is in a closed position, that is, when the lapping arms are in an unclamped position. When the lapping arms are clamped at the end of a lapping operation, the lever 324 swings in a clockwise direction (Fig. 3) and the switch 323 automatically opens.

Connected in series with the switches 331 and 323 is a normally open switch 325 which is mounted on the upper surface of the footstock 23. The switch 325 is arranged to be actuated by a bell crank lever 326 which in turn is rocked by means of a cam 327 carried by the footstock center 51.

The solenoid 316 is connected in series with the switches 331, 323 and 325 so that when the lapping machine is set in motion, the electrical interlock above disclosed is arranged so that the headstock clutch cannot be engaged until the work center has moved to an operative position and the clamping mechanism has been actuated to release the lapping arm. When the solenoid 316 is energized, the rock arm 315 is rocked in a clockwise direction (Fig. 3) to shift the headstock clutch 256 into engagement to rotate the headstock and thereby to effect a lapping operation. An electrical time delay relay 335, shown diagrammatically in Fig. 3, may be any of the standard commercial time relays which are in common use in the machine tool field. As illustrated in Fig. 3, a relay known commercially as the "Microflex instantaneous reset timer" manufactured by the Eagle Signal Corporation under United States Patent No. 1,794,762 may be employed.

The time delay relay 335 is connected in the electrical circuit so that when the main control valve 123 and its actuating lever 124 are moved into the full line position (Fig. 3), the electric switch 331 is shifted into the position illustrated in Fig. 3 which serves to start the time delay relay 335 in motion. In this position the valve 123 is moved to admit fluid under pressure to shift the valve 103 so as to admit fluid under pressure to the various mechanisms of the machine. When the footstock center 51 is moved toward the left (Fig. 3) into operative engagement to support a work piece in the machine, the switch 325 is closed. Similarly, when the clamping mechanism shaft 221 is rotated in a counterclockwise direction (Fig. 3) to unclamp the lapping arms for a lapping operation, the switch 323 is closed. These switches serve to complete the circuit from the power lines 336 to energize the solenoid 316 and thereby to shift the headstock clutch into engagement to rotate the work piece and thereby initiate a lapping operation. The lapping operation continues for a predetermined time interval as governed by the adjustable time delay relay 335. Shortly after the lapping operation starts, a contact within the time delay relay 335 is broken, thereby deenergizing the solenoid 316. The lapping operation proceeds for a definite and predetermined time interval, after which a contact within the time delay relay 335 is made to energize the solenoid 318 to rock the arm 315 and the shaft 255 in a counterclockwise direction (Fig. 3) to disengage the headstock clutch 256 and thereby stop the rotation of the work piece being lapped. The time delay relay continues to function and after a slight interval of time has elapsed, a solenoid 330 is energized to cause a downward movement of the solenoid armature 329 to move the arrow-headed plunger 328 downwardly, thus permitting the released tension of the spring 131 to shift the control lever 124 and the valve 123 in a clockwise direction (Fig. 3) so that the control lever assumes the position 124a illustrated in broken lines in Fig. 3.

As switch 340 is actuated by movement of the rock arm 315. In case the solenoid 318 fails to function before the circuit is closed to energize the solenoid 330, the automatic shifting of the valve 123, through the arm 322, shifts the switch 331, closing the upper contacts therein. These contacts are connected in series with the switch 340 and the solenoid 318 so that current is again passed to energize the solenoid 318 to disengage the headstock clutch. The valve 103 cannot be shifted toward the right (Fig. 3) until the headstock clutch is disengaged and the stop 250 withdrawn. It will be readily apparent from the foregoing disclosure that an electrical interlock and timing device is provided whereby the duration of the lapping operation may be accurately controlled and the main control valve, the clamping mechanism, the footstock, and the headstock clutch interlocked electrically so that the lapping operation cannot be started until the other mechanisms of the machine have completed their operative movement.

The operation of this improved machine will be readily apparent from the foregoing disclosure. A work piece, such as a camshaft or a crankshaft 24, to be lapped is laid in position on a work supporting cradle 345 which is supported on the table 21 between the head stock 22 and footstock 23, and the flange of the crankshaft is positioned with the aligning hole in engagement with a driving pin on the headstock. In this position of

the machine, the valve stem 104 is in its rearward position, that is, its right-hand end position (Fig. 3), and the control lever 124 is in the broken line position 124a. The control lever 124 is then moved in a counterclockwise direction to shift the valve 123 so as to admit fluid under pressure through the pipe 126 into the chamber 127 to cause the valve stem 104 and the valve piston formed integrally therewith to move toward the left (Fig. 3), which movement operates first to admit fluid under pressure through the pipe 115 and pipe 72 to move the footstock center 51 into supporting engagement with the end of the work piece. This movement serves also to close the switch 325. At the same time, fluid passing through the pipe 115 enters the cylinder chamber 116 to cause a downward movement of the piston 86 (Fig. 2) to move the toggle levers 94 and 95 from their dotted line position into the full line position (Fig. 2) to rock the arms 80 and the entire lapping arm assembly into an operating position, which movement withdraws the stop plunger 280 and permits a further forward movement of the valve stem 104.

The pressure being applied within the chamber 127, as soon as the stop plunger 280 is withdrawn the valve stem 104 moves automatically to its next position and fluid under pressure is admitted through the pipe 155 to the manifold or pipe 153 which conveys fluid to all of the lapping arm cylinders to actuate the toggle levers on each arm and thereby swing the lap supporting arms or jaws into an operating position to hold the lapping element, namely the continuous strips of abrasive paper or cloth, in lapping engagement with all of the crankpins and bearings of the shaft. This movement serves through the Bowden wire or cable 273 to rock the bell crank 302 in a counterclockwise direction to withdraw the stop plunger 300, thus permitting a further movement of the valve stem 104 toward the left (Fig. 3). The continued automatic movement of the valve serves to open a port and admit fluid under pressure through the pipe 304 to the lapping arm clamping motor 230 which rotates the shaft 221 and the disk 266 to unclamp the lapping arms. Rotation of the disk 266 in a counterclockwise direction (Fig. 3) serves through the Bowden wire or flexible cable 310 to rock the lever 311 in a counterclockwise direction so that it is out of the path of the projection 313 of the bell crank lever 254, which renders the headstock mechanism operative. At the same time, the rotation of the shaft 221 serves through the lever 324 to close the switch 323, thus completing a circuit to energize the solenoid 316 which in turn engages the headstock clutch to start the rotation of the work and to start the lapping operation on all of the crankpins and main bearings.

After the lapping operation has started, a contact within the time delay 335 opens, thereby deenergizing the solenoid 316. The lapping operation continues for a definite time interval, after which the electrical time delay relay 335 closes a contactor to energize the solenoid 318 to disengage the headstock clutch 256 and thereby stop the lapping operation. During the lapping operation, the stop plunger 250 is in an operative position so as to prevent accidental shifting of the valve stem 104 toward the right (Fig. 3). When the headstock is automatically stopped by the time delay relay, the bell crank 254 (Fig. 3) is rocked in a clockwise direction which serves to rock the bell crank lever 252 in a counterclock-

wise direction and thus withdraw the stop plunger 250 so that the valve stem 104 may be moved toward the rear or toward the right (Fig. 3). After the headstock clutch has been disengaged, another contactor within the electrical time delay relay is made to energize the solenoid 330 and thereby withdraw the plunger 328 so that the released tension of the spring 131 will rock the control lever 124 in a clockwise direction into the broken line position 124a, thus reversing the position of the main control valve so as to admit fluid under pressure through the pipe 129 into the valve chamber 128 to start the movement of the valve stem 104 toward the right (Fig. 3). This movement of the valve stem 104 continues until the stop collar 248 engages the stop plunger 260.

During this movement the valve shifts so as to admit fluid under pressure through the pipe 305 to the lapping arm clamping motor 230 to rotate the shaft 221 in a clockwise direction (Fig. 3) to clamp all of the lapping arms in an indexed position. This movement serves to pull the Bowden wire 310 to cause a counterclockwise movement of the lever 311 to swing downwardly into the path of the projection 313 of the bell crank 254 and thus lock the headstock so as to prevent starting the work rotation while all of the lapping arms are clamped in an indexed position. At the same time the clamping mechanism is being operated, the lever 324 rocks in a clockwise direction, thus permitting the switch 323 to open, thereby opening the circuit so as to render the solenoid 316 inoperative.

At the same time, the rotation of the disk 266 in a clockwise direction pulls the Bowden wire or cable 263 to move the bell crank 262 in a counterclockwise direction and thereby withdraw the stop plunger 260, thus permitting the valve stem 104 to be automatically moved by fluid under pressure toward the rear or right, as shown in Fig. 3. The valve stem 104 may then be moved until the stop collar 248 engages the stop plunger 270 which serves to open a port so as to admit fluid under pressure through the pipe 156 into the manifold or pipe 154 which causes a downward movement of all of the pistons within the lapping arm cylinders to actuate all of the toggle levers and to open the lap supporting members or jaws. During the opening of the lap supporting members or jaws, the cable 273 is pulled to rock the bell crank lever 272 in a clockwise direction (Fig. 3) to withdraw the stop plunger 270, thus permitting the valve stem 104 to be automatically moved by fluid under pressure into its extreme rearward or right-hand position. This movement of the valve serves to open the port so as to admit fluid under pressure through the pipe 75 into cylinder chamber 74 to withdraw the footstock center 51 and to admit fluid under pressure through the pipe 118 into the cylinder chamber 117 of the cylinder 84 to cause the arms 80 to swing the entire lapping arm assembly to an inoperative position, after which the lapped crankshaft may be removed from the machine.

A latch 360 is provided to facilitate holding the control lever 124 in a central or neutral position 124b (Fig. 1). In this position of the lever, the valve 123 is positioned to allow by-passing of fluid between valve chambers 127 and 128 of the valve 103, so that the valve 103 may be readily actuated manually in setting up the machine.

This invention is an improvement over my in-

vention set forth in the copending U. S. application Serial No. 233,003 filed October 3, 1938.

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

I claim:

1. A lapping machine having a plurality of lapping arms, a rotatable work support including a headstock and a footstock, a carrier to support said arms which is movable to and from an operative position, a fluid motor for actuating each of said members, a control valve to control the flow of fluid under pressure to all of said fluid motors, and a pilot valve to shift said control valve to start the lapping cycle.

2. A lapping machine having a plurality of lapping arms, a rotatable work support including a headstock and a footstock, a carrier to support said arms which is movable to and from an operative position, a fluid motor for actuating each of said members, a control valve therefor, a plurality of stops to interrupt the movement of said valve, connections between each of said stops and one of said elements, and a manually operable pilot valve to shift said control valve to start the lapping cycle and to maintain a pressure on said control valve so that it is automatically and progressively moved from one position to another as the stops are successively and intermittently withdrawn.

3. A crank shaft lapping machine having a plurality of lapping arms, a carrier to support said arms which is movable to and from an operative position, a lapping arm clamping mechanism to clamp said arms in an indexed position relative to said carrier, a rotatable work support including a headstock and a footstock, a separate fluid motor for actuating each of said members, a control valve therefor, means including an electrically operated clutch to start and stop said headstock, an electrical interlock including a valve actuated switch, a footstock actuated switch, and a clamping mechanism actuated switch, each of said switches being connected in series with said electrically operated clutch mechanism to prevent starting said headstock until the footstock is in supporting engagement with said work piece and the clamping mechanism has unclamped the lapping arms.

4. A lapping machine having a plurality of lapping arms, a rotatable work support including a headstock and a footstock, a carrier to support said arms which is movable to and from an operative position, a fluid motor for actuating each of said members, a control valve therefor, a pilot valve to shift said control valve to start the lapping cycle, an electrical interlock including an electrically operated headstock clutch, a footstock actuated switch, and electrical connections therebetween to prevent actuation of said clutch to start the work rotation until the headstock is in supporting engagement with a work piece.

5. A lapping machine having a plurality of lapping arms, a rotatable work support including a headstock and a footstock, a carrier to support said arms which is movable to and from an operative position, a lapping arm clamping mech-

anism, a fluid motor for actuating each of said members, a control valve therefor, a pilot valve to shift said control valve to start the lapping cycle, an electrical interlock including an electrically operated headstock clutch, a clamping mechanism actuated switch, and electrical connections therebetween to prevent actuation of said clutch to start the work rotation until the headstock is in supporting engagement with a work piece.

6. A lapping machine having a plurality of lapping arms, a rotatable work support including a headstock and a footstock, a carrier to support said arms which is movable to and from an operative position, a lapping arm clamping mechanism, a fluid motor for actuating each of said members, a control valve therefor, a pilot valve to shift said control valve to start the lapping cycle, an electrical interlock including a solenoid actuated headstock clutch, a footstock actuated switch, a clamping mechanism actuated switch, and a control valve actuated switch, said switches being interconnected with said solenoid so as to prevent engagement of said clutch until each of said switches has been actuated.

7. In a lapping machine having a plurality of lapping arms, a rotatable work support including a headstock and a footstock, a carrier to support said arms which is movable to and from an operative position, a lapping arm clamping mechanism, a fluid motor for actuating each of said members, a control valve to control the admission of fluid under pressure to all of said motors, a main control valve to admit fluid under pressure to either end of said control valve, a plurality of stops intermittently to interrupt the progressive movement of said control valve, connections between each of said stops and one of said elements automatically to withdraw said stop after the element has functioned, and automatically actuated means to shift said control valve to start a lapping cycle automatically to move said valve intermittently as successive stops are withdrawn.

8. In a lapping machine having a plurality of lapping arms, a rotatable work support including a headstock and a footstock, a carrier to support said arms which is movable to and from an operative position, a lapping arm clamping mechanism, a fluid motor for actuating each of said members, a control valve to control the admission of fluid under pressure to all of said motors, a main control valve to admit fluid under pressure to either end of said control valve, a plurality of stops intermittently to interrupt the progressive movement of said control valve, connections between each of said stops and one of said elements automatically to withdraw said stop after the element has functioned, automatically actuated means to shift said control valve to start a lapping cycle automatically to move said valve intermittently as successive stops are withdrawn, an electrical time delay relay, and an automatically actuated mechanism to shift said main control valve into a reverse position to stop the lapping cycle after the lapping operation has continued for a predetermined time interval as governed by said time delay relay.

9. A lapping machine having a plurality of lapping arms, a rotatable work support including a headstock and a footstock, a carrier to support said arms which is movable to and from an operative position, a fluid motor for actuating each of said members, a control valve therefor, a pilot valve to shift said control valve to start the lapping cycle, an electrically operated headstock clutch, a valve actuated switch, and an electrical time delay relay rendered operative by actuation of said valve actuated switch to actuate said electrically operated headstock clutch to initiate a lapping operation, said time delay relay being so constructed and connected as to actuate said electrically operated headstock clutch after the lapping operation has proceeded for a predetermined time interval to stop rotation of said headstock and work piece.

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