

May 1, 1945.

H. V. CHRISTENSEN

2,375,079

THREAD GRINDING MACHINE

Filed Feb. 22, 1943

9 Sheets-Sheet 1

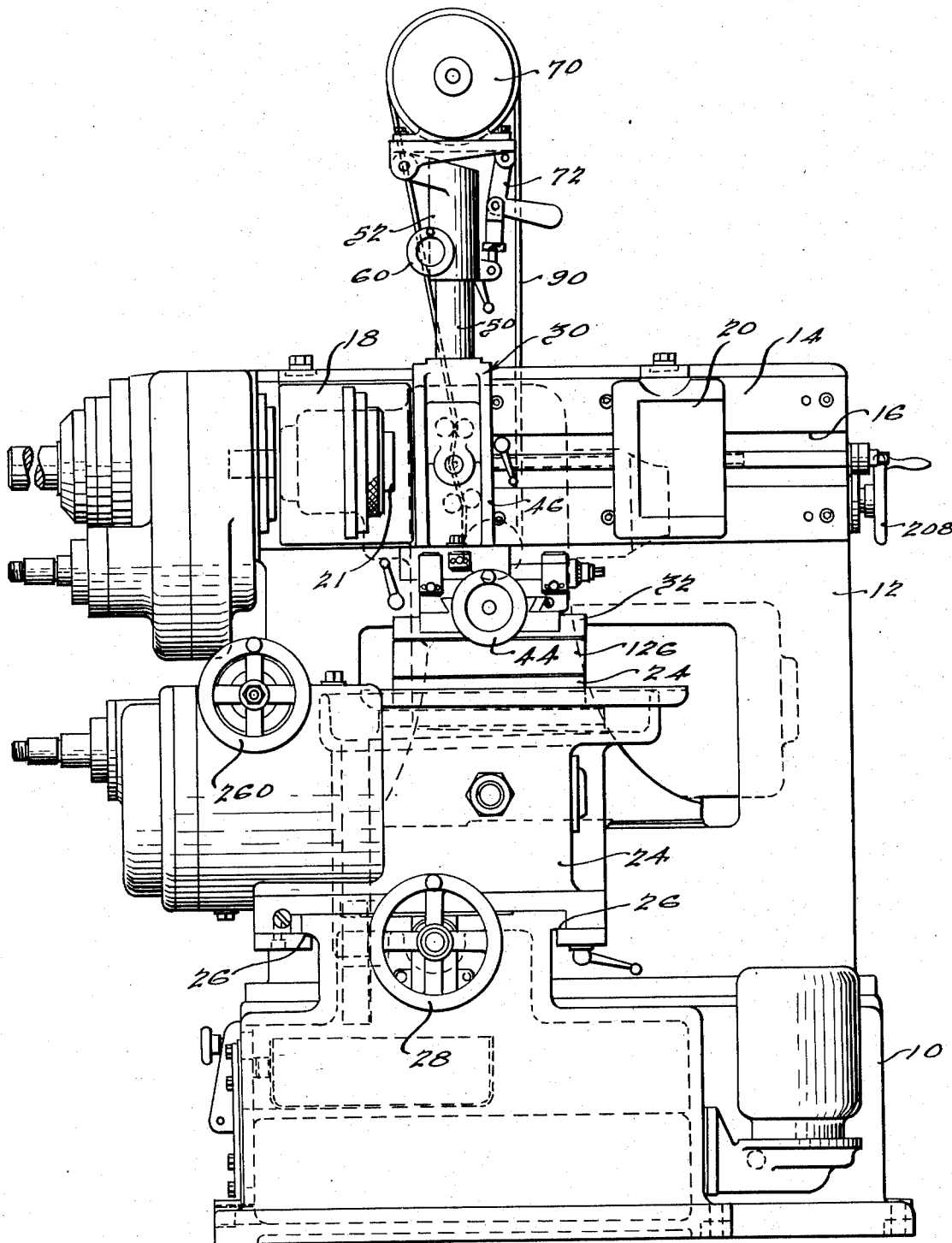


FIG. 1.

INVENTOR

Harold V. Christensen.

BY

Harness, Dickey & Pierce.

ATTORNEYS.

May 1, 1945.

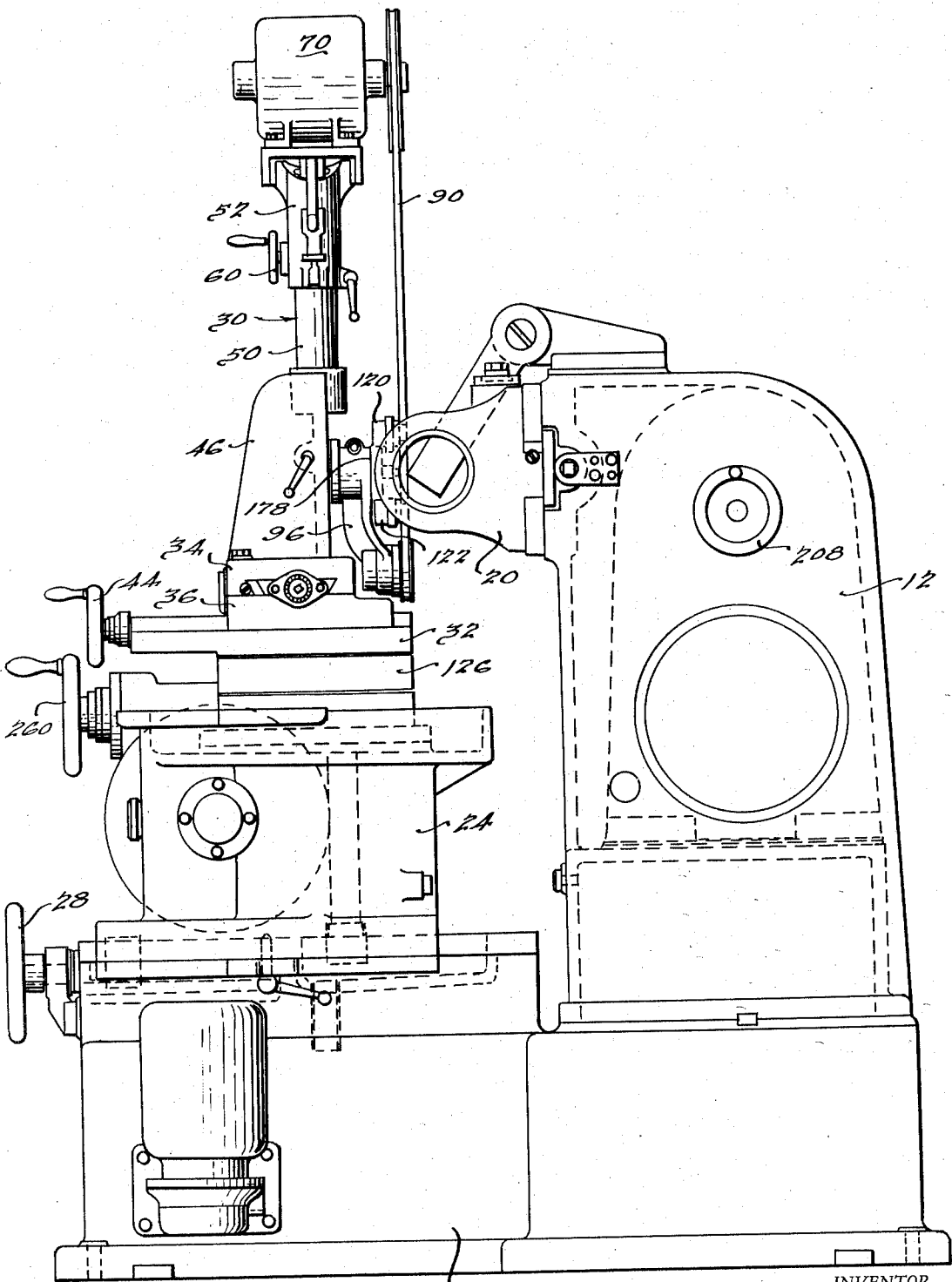
H. V. CHRISTENSEN

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9 Sheets-Sheet 2



INVENTOR
Harold V. Christensen.
BY
Harness, Dickey & Pierce.
ATTORNEYS.

May 1, 1945.

H. V. CHRISTENSEN
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2,375,079

9 Sheets-Sheet 4

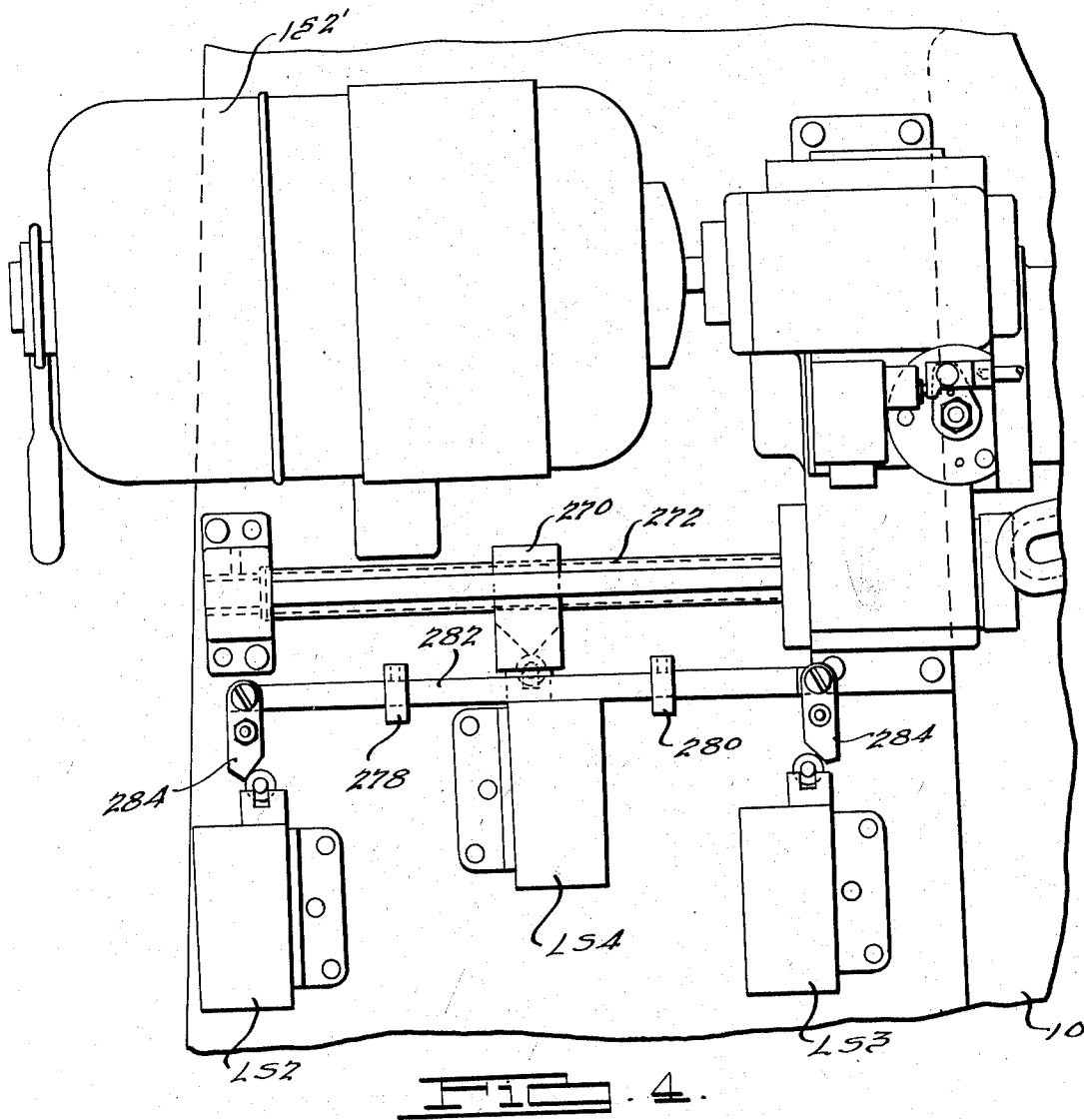


FIG. 4.

INVENTOR
Harold V. Christensen.
BY
Harness, Dickey & Pierce.
ATTORNEYS.

May 1, 1945.

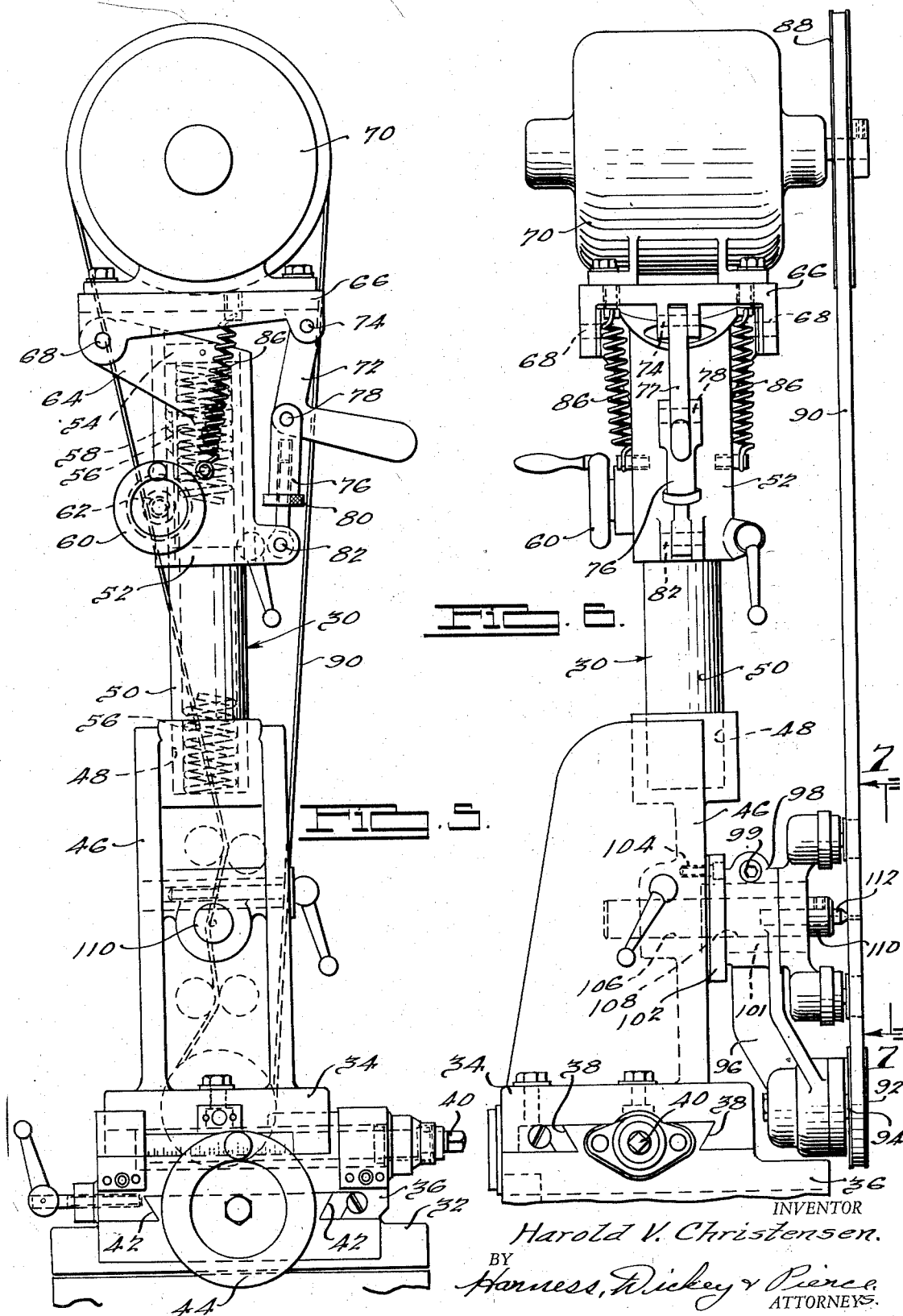
H. V. CHRISTENSEN

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9 Sheets-Sheet 5



May 1, 1945.

H. V. CHRISTENSEN

2,375,079

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9 Sheets-Sheet 6

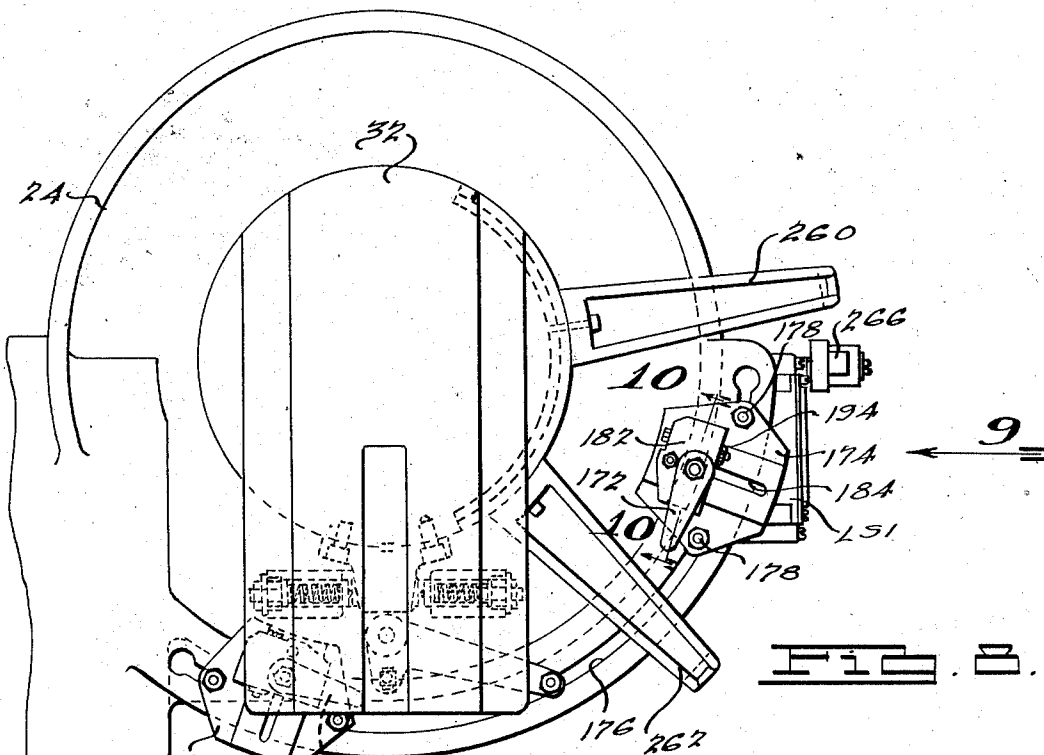


FIG. 8.

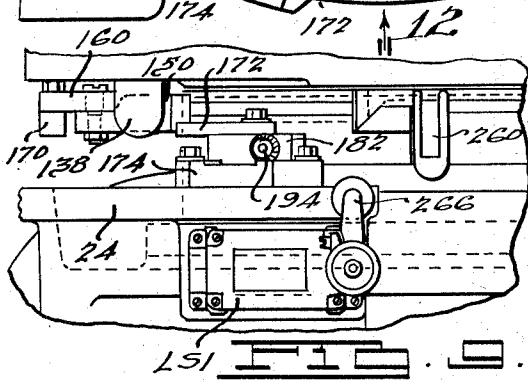


FIG. 9.

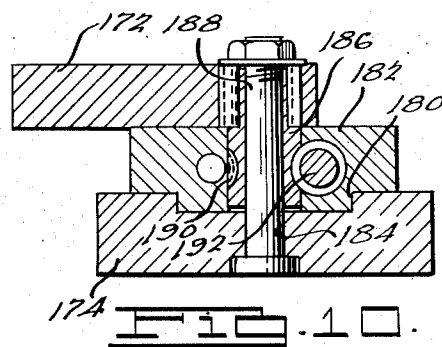


FIG. 10.

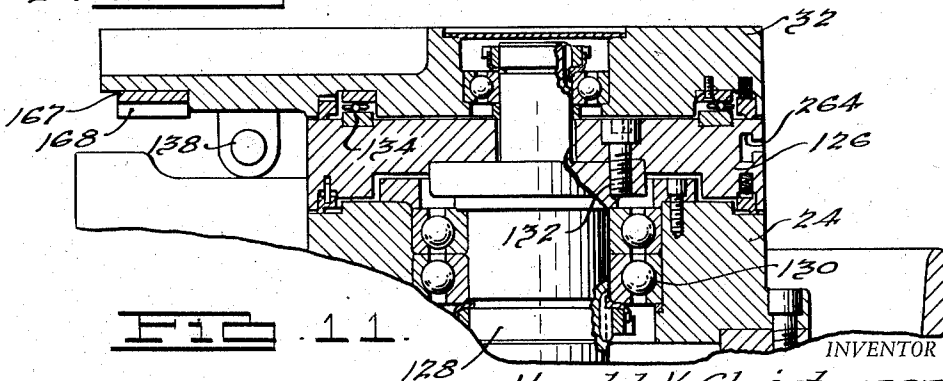


FIG. 11.

INVENTOR
Harold V. Christensen
BY
Harness, Dickey & Pierce
ATTORNEYS.

May 1, 1945.

H. V. CHRISTENSEN
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9 Sheets-Sheet 7

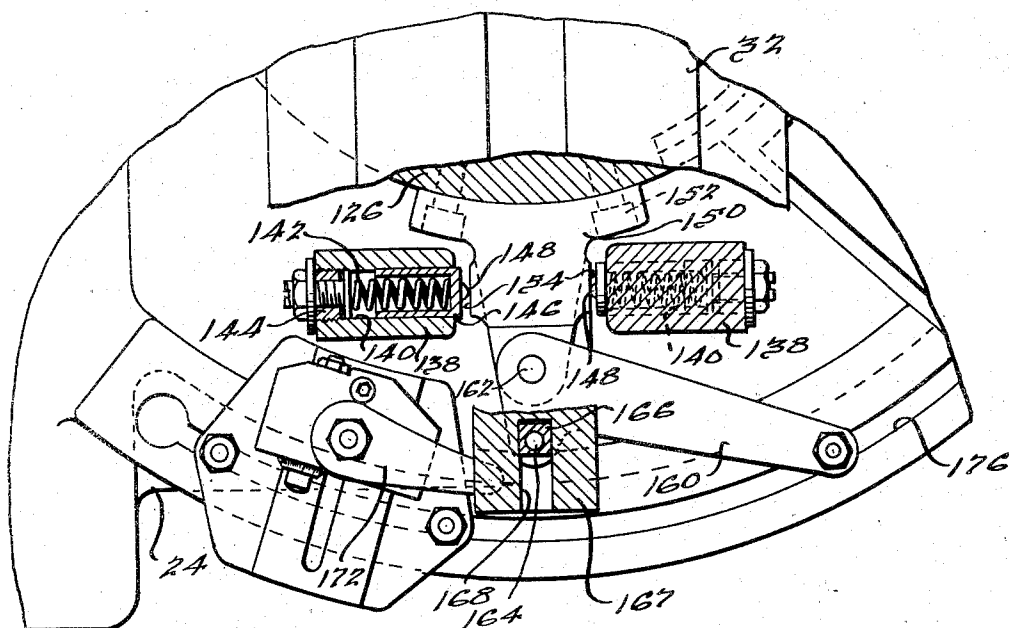


FIG. 13.

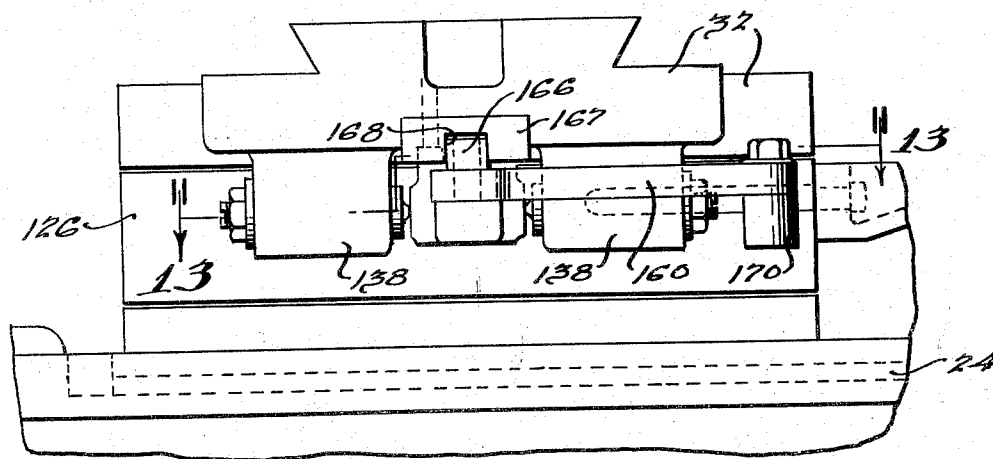


FIG. 12.

INVENTOR
Harold V. Christensen.
BY
Harness, Wickey & Pierce.
ATTORNEYS.

May 1, 1945.

H. V. CHRISTENSEN
THREAD GRINDING MACHINE

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9 Sheets-Sheet 8

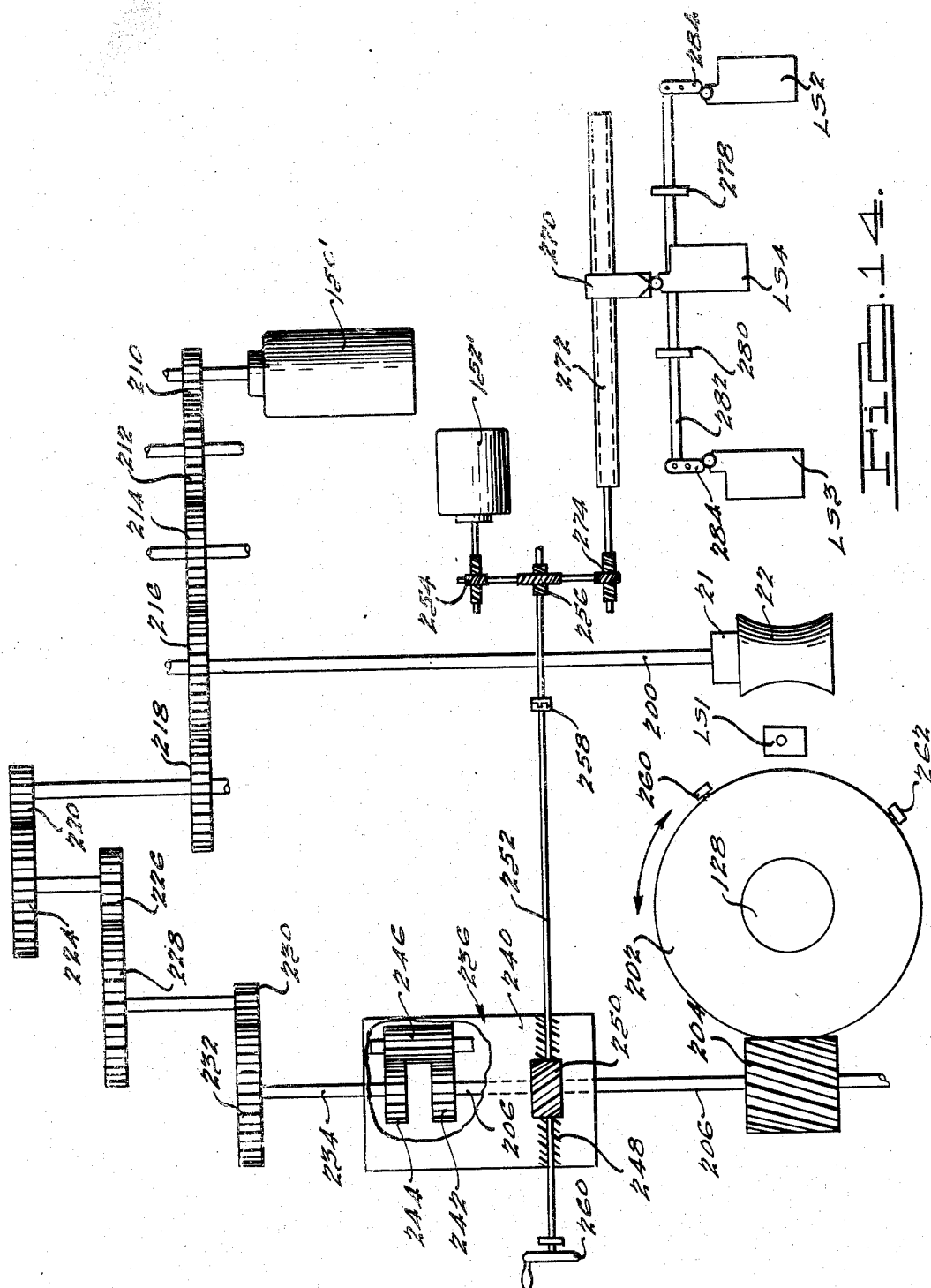


FIG. 14.

INVENTOR
Harold V. Christensen.
BY
Harness, Dickey & Pierce.
ATTORNEYS.

May 1, 1945.

THREAD GRINDING MACHINE

Filed Feb. 22, 1943

9 Sheets-Sheet 9

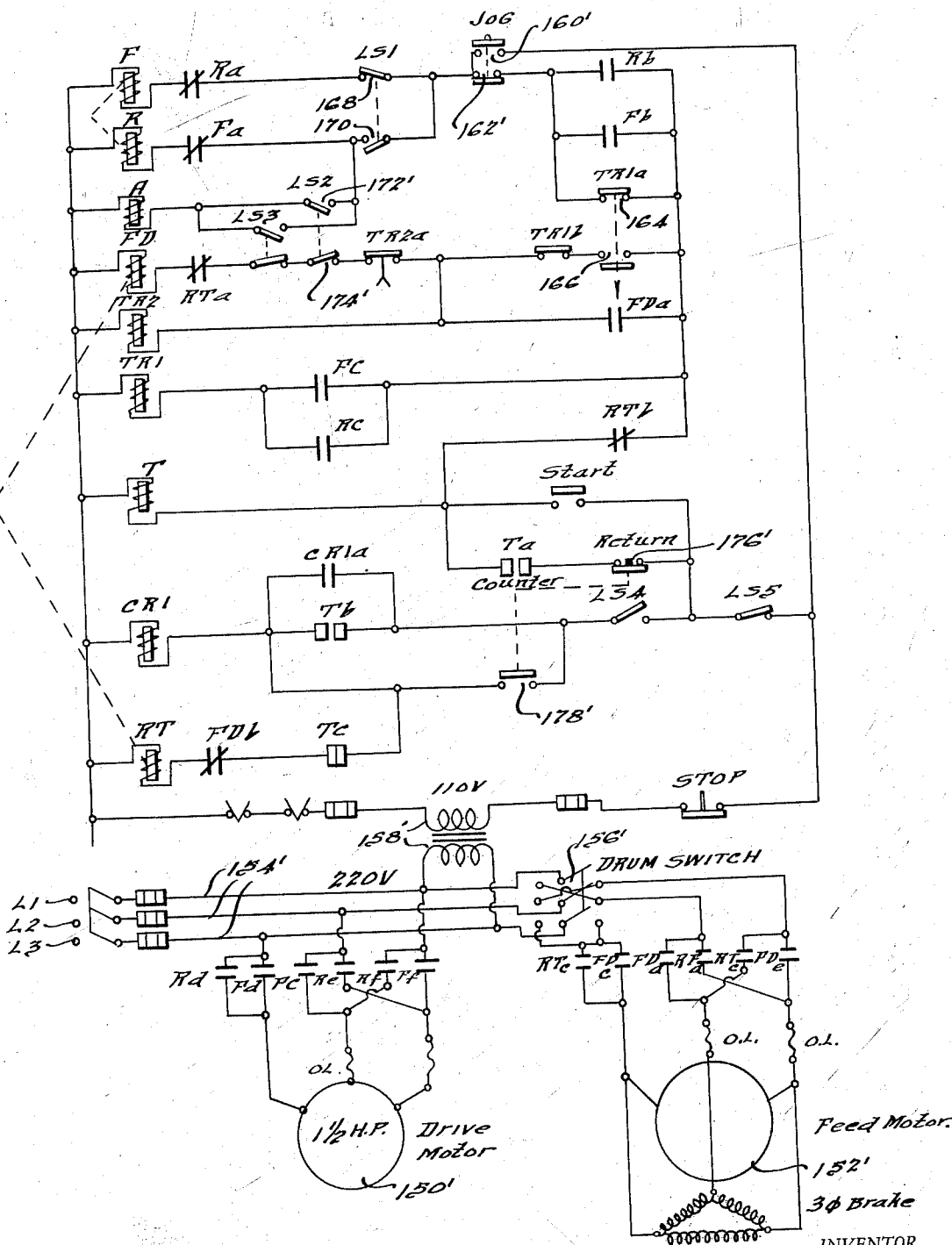


Fig. 15.

INVENTOR
Harold V. Christensen.
BY
Harness, Wickey & Pierce.
ATTORNEYS.

UNITED STATES PATENT OFFICE

2,375,079

THREAD GRINDING MACHINE

Harold V. Christensen, St. Clair Shores, Mich., assignor to Michigan Tool Company, Detroit, Mich., a corporation of Delaware

Application February 22, 1943, Serial No. 476,729

7 Claims. (Cl. 51—142)

The present invention relates to apparatus for polishing worms for use in worm gearing, and particularly relates to improvements in the apparatus disclosed in the co-pending application of George R. Scott, Serial No. 417,647, filed November 3, 1941, and which is now Patent No. 2,337,776.

One of the primary objects of the present invention is to provide improvements in machines of the type mentioned in which worms may be polished in an improved manner, particularly in which the thread form may be more accurately and quickly polished than in prior machines.

Another object of the invention is to provide improvements in machines of the type mentioned, in which the polishing belt is so mounted as to be positioned adjacent the work for accurately polishing worms of different helix angles.

A further object of the invention is to provide an adjustable guide for the belt in machines of the type mentioned, in which the guide is so positioned adjacent the work that the entering and leaving positions of the belt may be varied for worms of different helix angles.

Another object of the invention is to provide improvements in belt mountings of the type mentioned, so that the belt may be quickly released for changing.

Another object of the invention is to provide improvements in the operating mechanism of machines of the type mentioned for accomplishing an oscillating action of the work element.

Another object of the invention is to provide improvements in machines of the type mentioned, so that the belt is mounted and caused to follow the contour of the worm thread, and particularly to follow the contour of threads having end relief as shown in Scott Patent No. 2,279,414, issued April 14, 1942.

Other objects of the invention will become apparent from the following specification, the drawings relating thereto and from the claims hereinafter set forth.

In the drawings, in which like numerals are used to designate like parts in the several views throughout:

Figure 1 is a front elevational view of a polishing machine embodying features of the present invention;

Figure 2 is a side elevational view of the machine shown in Figure 1, and taken from the right side of Figure 1;

Figure 3 is a top plan view of the machine shown in Figure 1;

Figure 4 is a partial side elevational view of

the machine, and taken from the left side of Figure 1;

Figure 5 is a front elevational view of the work head and showing the manner in which the belt is mounted on such head;

Figure 6 is a side elevational view of the structure shown in Figure 5 and taken from the left side of Figure 5;

Figure 7 is an elevational view of the guide mechanism taken substantially along the line 7—7 of Figure 6;

Figure 8 is a top plan view of the work table;

Figure 9 is a side elevational view of a portion of the structure shown in Figure 8, and taken in the direction of the arrow 9, of Figure 8;

Figure 10 is a cross-sectional view taken substantially along the line 10—10 of Figure 8;

Figure 11 is a fragmentary, vertical, cross-sectional view showing the mounting and drive structure for the table shown in Figure 7;

Figure 12 is a partial end elevational view taken in the direction of the arrow 12 of Figure 8 and leaving out one of the end relief controls for purpose of clarity;

Figure 13 is a cross-sectional view taken substantially along the line 13—13 of Figure 12, and showing the end relief control omitted from the view of Figure 12;

Figure 14 is a diagrammatic view of the driving mechanism of the machine of the present invention; and

Figure 15 is a diagrammatic view of the electric control panel employed in the present invention.

In general, in the machine of the present invention, a worm gear of the type disclosed in Scott Patent No. 2,279,414, with or without the end relief there claimed, is ground or polished by means of an abrading element which is caused to engage the side of the thread of the worm. The worm is mounted on a horizontal spindle and the grinding or polishing element, which in the embodiment illustrated is in the form of an endless abrading belt, is mounted upon a vertical spindle. The belt is urged into engagement with the side of the thread and is caused to oscillate in synchronism with the reversed rotation of the worm spindle so that that portion of the belt which engages the worm follows the contour of the worm thread from one end to the other and return, repeating this until the thread is properly ground.

Referring to the drawings, the machine comprises a base 10 having an upstanding standard 12 disposed at the back thereof. Such back portion 12 has a vertical face 14 formed with a hori-

zontal guideway 16 which is adapted to have slidably mounted thereon a head stock 18 and a tail stock 20. The head stock 18 has the drive spindle 21 disposed therein for driving a worm 22 to be ground. The head and tail stock 18 and 20 are slidable within the guideway 16 for the purpose of properly positioning them and may be fixed in place upon the guideway 16 in the usual way.

A supporting standard 24 is mounted on the base 10 and is slidably supported on horizontal guideways 26 which are disposed at a right angle to the axis of the worm 22. The standard 24 is slidable on such guideways and is connected to the base 10 through a conventional screw and nut connection having a hand wheel 28 associated with the screw for the purpose of adjustably positioning the standard 24 with respect to the axis of the worm so that it may be set at the proper center distance with respect thereto.

Grinding or polishing means generally indicated at 30 is mounted on the support 24 for oscillation with respect thereto and for bodily movement therewith so that it may be disposed on the proper center distance with respect to the worm.

The grinding or polishing means 30 is mounted upon a top table 32 (Figures 1, 5, 8 and 11) through interconnecting means which permit adjustment in two directions, at right angles to each other, so that the grinding means may be properly positioned with respect to the worm thread. Such means 30 includes a base 34 which is interconnected to a member 36 through guideways 38. A screw and nut interconnection is provided between the member 34 and the member 36 for the purpose of slidably adjusting the member 34 with respect to the member 36 along guideways 38. The screw has a square head, indicated at 40, which may be engaged by a suitable tool to provide the adjustment, and Vernier scales are provided to indicate the position of the adjustment. A suitable locking means may be provided to lock the member 34 in its adjusted position with respect to the member 36.

The member 36 is connected to the member 32 by means of parallel guideways 42, which are disposed at a right angle to the guideways 38. The member 36 is interconnected to the member 32 by means of a conventional nut and screw having a hand wheel 44 connected to the outer end of the screw for the purpose of slidably adjusting the member 36 with respect to the member 32. Locking means may be provided for locking the member 36 in its adjusted position with respect to the member 32. Thus, the base 34 may be adjusted with respect to the member 32 by moving it in the directions of the guideways 38 and 42.

The base 34 includes an upstanding portion 46, which terminates in an upwardly opening, cup-shaped cylindrical recess 48. The recess 48 receives therein a vertical tubular post 50.

A tubular sleeve 52 having its upper end closed by means of a plate 54 is telescopically received over the upper end of the tubular member 50. A compression coil spring 56 is disposed within the tubular member 50, and the lower end of such spring rests upon the base of the recess 48 with the upper end bearing against the underside of plate 54 of the sleeve 52. This is to provide a resilient mounting for the sleeve member 52.

The sleeve member 52 may be adjustably positioned against the action of the spring 56, with respect to the tubular member 50, by means of a rack and gear connection, rack teeth 58 being formed in the peripheral surface of the tubular

member 50 adjacent the upper end thereof. A hand wheel 60 is mounted to the member 52 transversely of the axis thereof and is connected to a shaft having a gear 62 keyed thereto which is adapted to mesh with the rack teeth 58. Thus, by turning the hand wheel 60, the member 52 may be adjusted with respect to the member 50. The member 52 may then be locked in place by a conventional lock screw.

The member 52 has an integral bracket 64 formed adjacent the upper end thereof which serves to pivotally mount one end of a base plate 66 by means of pivot pins 68. A drive motor 70 is fixedly mounted to the top surface of the plate 66.

The end of the plate 66, opposite to that of the pivot 68, is connected to the member 52 by means of a toggle linkage including an L-shaped linkage member 72 which is pivotally connected to the member 66 by means of a pivot pin 74. The linkage member 72 is pivotally connected to the other link 76 of the toggle linkage by means of pivots 78. The link 76 is adjustable in length and is formed in two interengaging parts which are longitudinally movable with respect to each other for the purpose of adjusting the length of the link 76. One of such members may be in the form of a threaded screw which is received within a bore in the other member and a nut 80 may be provided for adjusting the length of the link. The lower end of the link is pivotally connected to the member 52 by means of a pivot pin 82. The purpose of the toggle link is to permit a quick downward pivoting of the base 66 about pivot 68 when the link 72 is broken so that the polishing belt may be quickly changed.

Tension springs 86 are disposed on opposite sides of the plate member 66 and have their upper ends connected to the plate member 66 and their lower ends connected to the sleeve member 52. The tension springs 86 serve to constantly urge the plate member in a clockwise direction (viewing Fig. 5) about pivots 68 so that when the toggle 72 is in the locked position shown in Fig. 5, it is held locked until manually released. The toggle is thus broken only by manual pressure against the action of springs 86.

A pulley 88 is keyed to the end of the motor shaft of motor 70 and is adapted to have an endless abrading belt 90 trained thereabout. The lower end of the abrading belt 90 is trained about a pulley 92. The pulley 92 is fixed to a shaft 94 and such shaft is rotatably mounted within suitable bearings mounted in the lower end of depending bearing bracket 96. The bearing bracket 96 has a split collar 98 provided with a tightening bolt 99, and such bracket is mounted to the standard 46.

The split sleeve 98 is received over a tubular member 101 having a flange 102. The member 101 is mounted to the standard 46 and secured thereto by means of suitable screws 104. The member 46 has a horizontal bore 106 there-through, and the bore 108 through the tubular member 101 is axially aligned with the bore 106. The split collar 98 may be received over the member 101 and secured thereto in its proper position by tightening the bolt 99.

A cylindrical member 110 is pressed into the bores 108 and 106, and such member 110 is provided with an axial recess in one end thereof which is adapted to removably receive the base of a cylindrical, pencil spindle 112. Such spindle 112 is removably disposed within the member 110, and may be secured therein by means of a set

screw or the like. The outer end of the member 112 is of a reduced and small diameter and is adapted to engage the inside of the abrading belt 90 so that the outer side of the belt, which carries the abrasive, is urged against the surface of the thread of the workpiece. The outer end of the pencil spindle 112 is of such a small diameter that it may readily extend between the threads of the worm and the reduced portion is of substantially the same length as the width of the belt. The width of the belt is substantially the same as the face depth of the worm thread.

In order to properly guide the entering and leaving portions of the belt, which will be caused to engage the worm thread in line contact by the pencil spindle, guide rollers are provided, as best shown in Figures 6 and 7. Such guide rollers include a pair of rollers 114 on one side of the spindle 112 and another pair of rollers 116 on the opposite side of the spindle 112. The pairs of rollers are mounted upon a mounting member having a hub portion 118 with outwardly extending ears 120 and 122. The rollers 114 are rotatably mounted on ear 120, and the rollers 116 are rotatably mounted on ear 122. The hub portion 118 is split and is disposed over the outer end of tubular member 101. The ears 120 and 122 are offset from a diameter with respect to each other, and the belt 90 passes between the rollers and about the spindle 112 so that the entering and leaving portions of the belt are at an angle with respect to each other. Such angle, in the embodiment illustrated, is approximately ten degrees and provides for clearance of the belt as it is urged into engagement with the worm thread so that the engagement of the belt with the worm is practically line contact.

The outer edge of member 101 is provided with a scale and it will be seen that the hub portion 118 may be rotated about member 101 and held in its adjusted position by means of a bolt 124, so that the belt may be adjusted to approach and leave the engaged portion of the worm thread at different angles. The guide rolls 114 and 116 are thus bodily adjusted about the spindle 112. The purpose of this is to accommodate the machine to worms of different helix angles.

As disclosed in the Scott patent, No. 2,279,414 above referred to, worms of the type for which the present machine is particularly useful are employed in the Cone type of double enveloping worm gearing. The flanks of the thread of the worm are sinuously warped surfaces, which surfaces are generated by a straight line element. This straight line element lies in a plane, passing through the axis of the worm and perpendicular to the axis of the wheel with which the worm is adapted to mesh. The intersections of these tooth flanks with this plane all lie along straight lines which are tangent to a circle whose center coincides with the axis of the wheel with which the worm is adapted to mesh.

In the present machine, the polishing or grinding means 30 is so positioned on the supporting table that the periphery of the spindle 112 on the entering side adjacent the side of the thread being worked upon is disposed on a tangent to the base circle of the worm gear or wheel with which the worm workpiece is adapted to mesh. The longitudinal axis of the spindle 112 is horizontally positioned so that it is in the midplane or axial plane of the workpiece as it moves across the worm. The thickness of the belt 90 is exaggerated in the drawings shown, and, in fact, it is quite

thin so that the belt will engage the workpiece along the line mentioned above.

As mentioned above, the grinding or polishing means 30 is mounted upon the top table 32. Such top table 32 is in turn mounted upon and interconnected to a main table 126. The tables 32 and 126 are interconnected together so that they are driven together, but relative movement is permitted between such tables in a manner that will be described in detail hereinafter.

The table 126 is rotatably mounted upon the standard 24, as best shown in Figure 11, and the table 126 is connected to and adapted to be driven by a vertical drive spindle 128, which is mounted within suitable bearings 130 within a vertical bore in standard portion 24. The table 126 is fixedly connected to the spindle 128 by means of bolts 132. The table 32 is supported on the top surface of table 126 by means of roller bearings 134, and a resilient driving connection is provided between tables 32 and 126 so that such tables are driven together.

Such resilient driving connection is best shown in Figures 12 and 13, and includes depending cylindrical members 138 which are formed integral with the undersurface of the overhanging portion of table 32. The cylindrical members have axially aligned bores 140 formed therein and each of such bores is adapted to receive therein a compression coil spring 142. A screw plug 144 is disposed in one end of each of the members 138, and bears against one end of the compression spring 142. The opposite end of each compression spring is received within a cup-shaped member 146, which is slidably disposed within the bore 140 and which has a semi-spherical knob 148 formed on the outer end thereof.

An outwardly projecting arm 150 is secured to the peripheral edge of table 126 by means of bolts 152, and such member 150 extends between the facing portions of members 138. Bearing surfaces 154 are formed on the member 150, and such bearing surfaces are adapted to have the projections 148 resiliently bear thereagainst. The opposite springs 142, in bearing against the member 150, provide the drive connection between tables 32 and 126, in either direction of drive of such tables. Such resilient means, however, permits limited relative movement between such tables.

The relative movement between the tables is provided so that the abrading member follows the contour of the worm thread when such worm thread is provided with the gradual end relief disclosed and claimed in Scott Patent No. 2,279,414, above referred to.

In the operation of the machine, the tables 126 and 32 are caused to oscillate with respect to the worm and the abrading belt engages the worm during such oscillation. The abrading means is rotated in one direction and the worm is rotated in one direction. The direction of rotation of both is then reversed so that the pencil spindle 112, in its engagement against the belt 90, passes from one end of the thread to the other end, then the direction of the pencil spindle and the worm are reversed, so that the pencil spindle returns to its first position while the worm is reversely turned.

The driving means for the spindles will be described hereinafter. Such driving means also includes a side feed means so that the grinding means, including the pencil spindle, are fed toward the side of the thread in order to remove the desired amount of material from the work-

piece. Such side feed mechanism will also be described hereinafter.

As the grinding belt engages the worm thread adjacent the ends of the thread, and when the worm is of the type having the end relief above referred to, means are provided to move the tables 32 and 126 relative to each other so that the pencil spindle urges the belt into engagement with the worm thread over those portions at the ends which have been gradually relieved as well as in the normal, central portion. Such means includes a bell crank member 160 which is fulcrumed to the outer end of member 150 by means of a pivot pin 162. One arm of the bell crank member 160 projects radially outwardly and has a pivot pin 164 connected thereto on which a square member 166 is mounted. The member 166 is received within a rectangular groove 168 of a member 167 which is secured within a groove in the undersurface of the overhanging end of table 32.

It will be appreciated that, as the bell crank 160 is rocked about its pivot 162, the member 166 will correspondingly rock about the pivot 164 and slide within slot 166 to cause a relative movement between tables 126 and 32 against the action of the resilient springs 142.

In order to accurately control the degree of such relative movement, the other arm of the bell crank member 160 has a roller follower 170 connected to the outer end thereof and depended therefrom. Such roller follower 170 is adapted to engage the cam surfaces of cam plates 172 as the tables 32 and 126 approach either end of their oscillation. The cam plates 172 have cam edges of proper contour, depending upon the contour of the end relief on the worm, and are adjustably supported on the standard portion 24 and may be set to give the desired contour and extent of end relief or may be positioned inwardly where they are out of the path of movement of the roller follower 170 when no end relief is present on the workpiece. In the drawings, the cams 172 are illustrated in such out-of-the-way position, but it will be readily apparent that they may be positioned so as to be engaged by the cam follower.

The mounting for the cam members 172 includes a base plate 174 which may be suitably positioned within a slot 176 formed on the periphery of standard portion 24. The plates 174 may be fixed in position in such slot by means of nuts and bolts 178.

Each member 174 is formed with a transverse guide slot 180 in the top surface thereof which slidably receives therein a mounting plate 182 having an undersurface complementary in shape to the groove 180. A slot 184 is formed through the member 174 and is adapted to receive a bolt 188 which passes through a central aperture in member 182 and through a tubular member 186, which projects upwardly within an aperture through member 172, for the purpose of fixing the member 182 in its proper position within slot 184. The member 172 is fixed to the upwardly projecting end of tubular member 186 for rotation therewith, and such member 186 is formed with gear teeth 190 on the peripheral surface thereof. The teeth 190 are adapted to mesh with the teeth of a worm 192 which is mounted within member 182 and which has an adjusting knob 194 fixed to the outer end of the worm shaft. The knob 194 may have suitable indicia thereon and when the knob is turned the cam plate 172 is caused to pivot about pivot bolt 188. Thus

the cam plates 172 may be adjusted to the proper position for the desired end relief contour.

With the members 172 positioned for the desired end relief, it will be appreciated that, when the roller follower 170 engages either of the cam members, the bell crank 160 is caused to rock to provide the relative movement between tables 32 and 126 which causes the spindle 112 to follow the thread form throughout its length.

The spindle 21, to which the workpiece 22 is attached, and the vertical spindle 128, to which the grinding means 30 is connected, are driven in synchronism. The spindle 21 is connected to a drive shaft 200; and the spindle 28 is connected through a worm gear 202 and worm 204 with a drive shaft 207. A main drive motor 150', which is a variable speed, reversible motor, is mounted on the standard 12 and has an outwardly extending shaft 207 associated therewith. A hand wheel 208 is connected to the outer end thereof for varying the speed of the drive.

The drive motor 150' is connected to the shaft 200 through change gears 210, 212, 214 and 216, the gear 216 being keyed to shaft 200. The shaft 206 is driven through the same change gears and in addition through change and reduction gears 218, 220, 224, 226, 228, 230 and 232. Gear 232 is keyed to a shaft 234 which is aligned with shaft 206.

The shafts 234 and 206 are interconnected through a matching differential generally indicated at 236. Such matching differential 236 may be of the same structure as the matching differential employed in the machine of Pelphrey application, Serial No. 435,649, filed March 21, 1942. The matching differential 236 is employed for the purpose of providing the relative side feed of the vertical spindle with respect to the horizontal spindle so that the abrading means is side fed with respect to the worm thread for the purpose of removing the desired amount of material from the worm.

The matching differential includes a cylindrical housing or rotatable drum 240, into which the aligned shafts 234 and 206 extend. The housing 240 is mounted for rotation within suitable bearings on the standard 10 and may be revolved about the axis of shafts 234 and 206. A gear 242 is keyed to the inner end of shaft 206 and another gear 244 is keyed to the inner end of shaft 234. An idler gear 246 is mounted within the housing 240 on a shaft which is mounted on suitable bearings therein, and such gear meshes with gears 244 and 242. The gear 246 is free to rotate about its own axis but revolves about the axis of gears 242 and 244 when the housing 240 is revolved. The gears 242 and 244 have the same outside diameter but gear 242 has less teeth than gear 244. For example, gear 244 may have twenty-four teeth, gear 246 have thirteen teeth and gear 242 twenty-three teeth. The gear center distances for the gears 242 and 244 with respect to gear 246 are the same. The twenty-four tooth gear may be made standard, while the twenty-three tooth gear is cut to mate with the thirteen tooth gear. All geometrical laws of the involute curve are strictly observed in the formation of these gear teeth.

The construction of the matching differential 236 thus provides a great gear reduction within itself for the side feed mechanism, as one turn of the housing or drum 240 rotates gear 242 one twenty-third of a revolution. Thus, it is possible through this means to accomplish the relatively

small side feed action directly through the main drive in a very accurate manner.

This side feed is accomplished by rotating the housing 240, and such housing is formed with a ring of worm gear teeth 248 therearound which mesh with a worm 250.

The drum is rotated by means of the side feed motor 152' which is connected to a drive shaft 252, to which the worm 250 is keyed. The motor 152' may be connected to the shaft 252 through gear reduction worm and gear sets 254 and 256.

A hand operated jaw clutch 258 is inserted between sections of the shaft 252 so that the drive shaft 252 may be thrown out of drive by the motor 152' and a side feed hand wheel 260, which is connected to the forwardly projecting end of shaft 252, may be hand operated to side feed by hand.

The side feed is either to right or left, depending upon which side of the worm thread is being worked upon. In the embodiment illustrated the grinding means is set to operate on the right side of the worm thread, viewing Figure 1, so that the side feed would be to the left. When the opposite side of the thread is to be worked upon the opposite reach of the belt 90 is engaged by the guide rollers with the guide rollers rotated through substantially 180° from the position shown. The table is also set so that the spindle is tangent to the base circle above referred to.

As mentioned above, the spindle 128 is caused to oscillate and the spindle 21 is correspondingly reversed in its direction of rotation. The variable speed motor 150' is reversible and control means are provided for reversing the direction of motor 150'. Such means include a limit switch indicated at LS1, which is disposed adjacent the periphery of table 126. Actuating arms 260 and 262 are secured to the table 126 within a T-slot 264 provided in the periphery thereof. Such members 262 may be suitably adjusted within such slots so as to effect the reversal at the proper time. The limit switch LS1 has an actuating arm 266 projecting upwardly therefrom in the path of movement of the reversing arms 260 and 262. Thus, when the table 126 is rotating in one direction one of the arms 260 or 262 strikes the actuating arm 266 of LS1 causing the motor 150' to reverse. In the reverse direction the other stop arm engages the actuating member 266 to cause another reversal.

Control means are also provided for controlling the extent of side feed and such control means includes limit switches LS2, LS3, and LS4, which have actuating arms disposed to be actuated by a traveling nut 270. The traveling nut 270 is mounted on a screw 272 which is operatively connected to the side feed motor 152' through a worm and gear set 274 and sets 254 and 256. As the screw 272 is caused to turn by the motor 152', the nut 270 is moved along the screw 272 in a direction depending upon the direction of rotation of motor 152'. When in one position, the central position LS4 is actuated and when in positions to the right or left, LS2 or LS3 are actuated through engagement of the nut with the stops 278 or 280 which are adjustably mounted on rod 282. Engagement of either of these stops causes shifting of rod 282 which causes actuation of either LS2 or LS3 through depending fingers 284 which engage the actuating arms of the limit switches.

In order to automatically control the operation of the present machine an electric control panel is diagrammatically illustrated in Figure 15.

Referring to Figure 15, the variable speed drive

motor 150' and side feed motor 152' are diagrammatically illustrated in their relation to the electric control panel. The drive motor 150' and the side feed motor 152' receive their current from main supply line 154'. A drum switch 156' is interposed in the main line adjacent the feed motor 152' and, when in the position shown, the feed is to the right. With the switch 156' positioned oppositely from that shown, the feed would be to the left. The current from the main line is supplied to the control panel through a transformer indicated at 158'.

In the setting up operation, it may be desirable to disconnect the feed mechanism by disengaging the clutch 258 and positioning the work by the hand wheel 260. If this is done, LS5 is opened by the clutch lever and the only operation that can now be performed is by the jog button. It will be seen from the diagram that when the jog button is depressed, the upper section thereof closes gap 160' and opens the lower gap 162' so that current is supplied coils and relays F' and R as LS1 is actuated.

In the normal operation of the machine, the clutch 258 is engaged and LS5 is closed, as shown. Pressing of the start button energizes counter or timer clutch coil T through LS5 and such coil T establishes its own holding circuit through normally open contact Ta which closes when T is energized. At this stage in the operation, contact TR1a is in the position shown with the upper contact closing gap 164 and with the lower contact open across gap 166. With LS1 in the position shown, coil or relay F is energized across gap 164' through TR1a, LS1 and normally closed contact Ra.

When coil F is energized, normally closed contact Fa is opened and normally open contacts Fb, Fc, Fd, Fe, and Ff are closed. With Fd, Fe, and Ff closed, the drive motor 150' turns in the forward direction until LS1 is actuated by one of the stops 260 or 262 on the table 126 to open gap 168' and close gap 170'. When gap 168' is opened, coil F is de-energized and Fa returns to its normally closed position so that coil R is energized across closed gap 170'. When coil R is energized, normally closed contact Ra is opened and normally open contacts Rb, Rc, Rd, Re, and Rf are closed. Contacts Fb, Fc, Fd, Fe, and Ff open and drive motor 150' is reversed to drive the table in the reverse direction until LS1 is again actuated to de-energize coil R and energize coil F. When coil F is de-energized and coil R energized, the circuit to TR1 is maintained through Rc.

When TR1 is energized, TR1a moves from the position shown upwardly to open gap 164' and close gap 166'; however, coils F or R are maintained energized through contacts Fe or Rb, depending upon the position of LS1.

When TR1 is initially energized, the top and bottom portions of the contacts TR1a act instantaneously to open gap 164' and close gap 166'.

The timer, including the coil TR1 and the contacts TR1a, is so constructed that upon energization of coil TR1 the upward movement of TR1a is instantaneous to close gap 166' and open gap 164'; but when TR1 is de-energized the downward movement of TR1a is pneumatically timed so that there is a predetermined lag between the de-energizing of TR1 and the closing of gap 164' and opening of gap 166'. This permits a time interval between the forward and reverse movement of the table or the energization of coils F

and R so that there is not a sudden stop and reversal in the machine parts.

There is an auxiliary contactor TR1b on the timer TR1 in series with the feed circuit which opens upon energization of coil TR1 preventing the energization of the feed coil FD during the time that RR1 is energized.

When LS1 is actuated, F or R is de-energized, depending upon the position of LS1 which in turn de-energizes TR1; and at this instant TR1b returns to closed position while the upper portion of TR1a across gap 164' is timed out, thereby completing the circuit to feed coil FD. With FD energized, FDC, FDD, and FDE are closed causing the feed motor 152' to run to obtain the feed until TR2 times out. Coil TR2 is energized through FDa, which is closed when FD is energized. The timer, including coil TR2 and contact TR2a, is such that when coil TR2 is energized, TR2a remains in the closed position shown for a timed interval at which time TR2a opens to de-energize FD. When FD is de-energized, the motor 152' stops when contacts FDC, FDa, and FDE open. Motor 152' is provided with a three-phase brake so that when the motor contacts are opened the motor is instantly braked to stop the feed.

It will thus be seen that the feed coil FD is energized at the end of each of the forward and reverse movements of the table or at each time that the reversal of motor 152' takes place. Also, from the above, it will be understood that there is a time period before the energization of coils F or R, such time period being controlled by the normally closed portion of TR1a across gap 164' which falls back to such normally closed position in accordance with the setting of the pneumatic timer mentioned above, to energize F and R.

The above action in the alternate energizing of coils F and R takes place and the incremental feed due to the energizing of coil FD takes place until the traveling nut 270, associated with the feed, has progressed to a point of actuating either LS2 or LS3, depending upon the position of the drum switch 156'. With the drum switch in the position shown, the feed is to the right, viewing Figure 14, so that the above action would not take place until LS2 was actuated. LS4 is held open when the traveling feed nut 270 is in the central position shown in Figure 14, but as soon as the nut moves away from its central position, which may occur after the first, or one of the first several, impulses of FD, LS4 closes and remains closed until the traveling nut returns to its central position and again engages LS4 to open it. At the initial stage of the operation, counter or timer clutch coil T is energized to close normally open contacts Ta and Tb so that the holding circuit for FR, FD, TR2, and TR1 is maintained through Ta when the start button is released. When Tb2 is closed, coil CR1 is energized so that it establishes its own holding circuit through CR1a and through LS4 when it is closed. When coil T is energized, normally closed contact Tc opens so that coil RT cannot be energized.

When LS2 is engaged, gap 172' is closed and gap 174' is opened. With gap 174' open, coil FD cannot be energized so that the feed is no longer operated at the reversals of F and R; but instead an actuating or impulse coil A is energized a preset number of times. At the last count of the preset number of times, the counter or timer clutch associated with coil T is mechanically opened so that coil T is de-energized thereby opening the entire control circuit above this point.

Before this takes place, that is, before the preset number of impulses to counter coil A takes place, there is no feed, but the alternate energizing of coils F and R continues so that the polishing band 90 continues to engage the work for a final finishing operation. That is, the polishing belt will continue to pass through the worm in engagement with the side of the thread for a preset number of times without side feed.

After counter coil A counts out and coil T is de-energized, the remainder of the cycle is devoted to returning the traveling nut to its center position. Tc will then return to its normally closed position and coil RT will be energized through normally closed contacts FDb, CR1a and closed LS4 and LS5. When the traveling nut reaches its central position, LS4 is opened so that coil RT is de-energized.

Going back to the beginning of the cycle, LS4 was initially held open by the normal, center position of the traveling nut. However, it is closed by spring action when the nut travels away from its central position. Nothing happens in this part of the circuit until the counter counts out normally closing contact Tb which energizes CR1 which sets up its own holding circuit through CR1a. When coil RT is energized through CR1a, contacts RTc, RTd, and RTE are closed to run the feed motor in the reverse direction until LS4 is opened by the traveling nut which instantaneously stops the feed motor through the three-phase brake. This terminates the normal cycle.

By the position of the drum switch, the above cycle of operation can be either to the right or to the left, which enables finishing the worm on either side of the worm thread. The above description has been with the feed to the right, but if the drum switch 156 were oppositely positioned, the feed would be to the left. Otherwise, the operation would be the same as that described above.

The jog button is provided for operating coils F and R only. The return button is provided in case the stop button should be depressed while on the return and so that the return only can be continued. That is, it will be seen that when the return button is actuated the gap 176' is opened and gap 178' closed. With gap 178' closed, RT and CR1 would be energized while all of the circuit above gap 176' would be open.

Normally closed contact RTa is provided in series with coil FD and normally closed contact FDb is provided in series with coil RT so that there can be no actuation of the return during feed nor can there be an actuation of the feed during return.

From the above description of the automatic cycle it will be understood that the normally open contacts are illustrated by the spaced parallel lines, and the normally closed contacts are illustrated by the spaced parallel lines having a cross line passing through the parallel lines. Energization of the various coils closes their respective normally open contacts and opens their respective normally closed contacts, such contacts being connected to their coils in the usual way. The contacts for the various coils or relays are indicated by sub-letters. The elements employed in the electric control circuit are conventional elements obtainable on the market and their structures are understood by those skilled in the art. What is claimed is:

1. Apparatus for polishing the thread sides of an area contact type of worm comprising a spindle for rotatably mounting a worm, a supporting table mounted for movement about an

axis coinciding with the axis of rotation of a worm wheel with which said worm is adapted to mesh, an endless polishing belt carried on said supporting table, said belt having a width generally the same as the depth of the thread of the worm being polished, means operatively connected to said belt for driving said belt, means mounted on said table adjacent said belt for engaging the inside of the belt and for urging the opposite side of said belt into engagement with the side of worm thread, and guide means mounted on said table and disposed on opposite sides of said last named means in engagement with the belt on the side opposite to that engaged by said last named means to control the entering and leaving positions of the belt with respect to said last named means.

2. Apparatus for polishing the thread sides of an area contact type of worm comprising a spindle for rotatably mounting a worm, a supporting table mounted for movement about an axis coinciding with the axis of rotation of a worm wheel with which said worm is adapted to mesh, an endless polishing belt carried on said supporting table, said belt having a width generally the same as the depth of the thread of the worm being polished, means operatively connected to said belt for driving said belt, means mounted on said table including a pencil spindle engaging the inside surface of said belt for urging said belt into engagement with the side of worm thread, guide means disposed on opposite sides of said pencil spindle in engagement with the belt on the side opposite to that engaged by said pencil spindle to control the entering and leaving positions of the belt adjacent said pencil spindle, and means mounting said guide means for bodily adjustment about the center of said pencil spindle so as to vary the entering and leaving positions of the belt with respect to the work adjacent said pencil spindle.

3. Apparatus for polishing the thread sides of an area contact type of worm comprising a spindle for rotatably mounting a worm, a supporting table mounted for movement about an axis coinciding with the axis of rotation of a worm wheel with which said worm is adapted to mesh, an endless polishing belt carried on said supporting table, said belt having a width generally the same as the depth of the thread of the worm being polished, means operatively connected to said belt for driving said belt, means mounted on said table including a pencil spindle engaging the inside surface of said belt for urging said belt into engagement with the side of worm thread, and guide means mounted on said table including rollers disposed on opposite sides of said pencil spindle in engagement with opposite sides of the belt on the side opposite to that engaged by said pencil spindle to control the entering and leaving positions of the belt adjacent said last named means, said rollers being so positioned with respect to each other and to said pencil spindle that the belt portions on opposite sides of said pencil spindle are at an angle with respect to each other.

4. Apparatus for polishing the thread sides of an area contact type of worm comprising a spindle for rotatably mounting a worm, a supporting table mounted for movement about an axis coinciding with the axis of rotation of a worm wheel with which said worm is adapted to mesh, an endless polishing belt carried on said supporting table, said belt having a width generally the same as the depth of the thread

of the worm being polished, means operatively connected to said belt for driving said belt, means mounted on said table including a pencil spindle engaging the inside surface of said belt for urging said belt into engagement with the side of worm thread, guide means including rollers disposed on opposite sides of said pencil spindle in engagement with the belt on the side opposite to that engaged by the pencil spindle to control the entering and leaving positions of the belt adjacent said pencil spindle, said rollers being so positioned with respect to each other and to said pencil spindle that the belt portions on opposite sides of said pencil spindle are at an angle with respect to each other, and means mounting said rollers for bodily adjustment about the center of said pencil spindle so as to vary the entering and leaving positions of the belt with respect to the work adjacent said pencil spindle.

5. Apparatus for polishing the thread sides of an area contact type of worm comprising a spindle for rotatably mounting a worm, a supporting table mounted for movement about an axis coinciding with the axis of rotation of a worm wheel with which said worm is adapted to mesh, an endless polishing belt carried on said supporting table, said belt having a width generally the same as the depth of the thread of the worm being polished, means operatively connected to said belt for driving said belt, means mounted on said table including a pencil spindle engaging the inside surface of said belt for urging said belt into engagement with the side of worm thread, guide means including rollers disposed on opposite sides of said pencil spindle in engagement with the belt on the side opposite to that engaged by said pencil spindle to control the entering and leaving positions of the belt adjacent said pencil spindle, said rollers being so positioned with respect to each other and to said pencil spindle that the belt portions on opposite sides of said pencil spindle are at an angle with respect to each other, and means mounting said rollers for bodily rotation about the center of said pencil spindle through substantially 180° so that when in one position the rollers engage one reach of the belt and when in the other position engage the other reach of the belt.

6. Apparatus for polishing the thread sides of an area contact type of worm comprising a rotatable spindle for rotatably mounting a worm, another spindle having a supporting table mounted thereon for rotative movement about an axis coinciding with the axis of rotation of a worm wheel with which said worm is adapted to mesh, means for rotating said spindles about their respective axes in synchronism first in one direction and then in the opposite direction, a belt supporting member mounted on said table for limited relative rotative movement with respect thereto, resilient means interconnecting said supporting member and table to resiliently urge said supporting member to a normal position with respect to said table, means connectible with said supporting member and responsive to movement of said supporting member for causing such relative movement by moving said supporting member out of its normal position, an endless polishing belt carried on said supporting member, means operatively connected to said belt for driving said belt, and means engaging the inside surface of said belt for urging said

belt into engagement with the side of the worm thread.

7. Apparatus for polishing the thread sides of an area contact type of worm comprising a rotatable spindle for rotatably mounting a worm, another spindle having a supporting table mounted thereon for rotative movement about an axis coinciding with the axis of rotation of a worm wheel with which said worm is adapted to mesh, means for rotating said spindles about their respective axes in synchronism first in one direction and then in the opposite direction, a belt-supporting member mounted on said table for

5 limited relative rotative movement with respect thereto, a pair of spaced cams stationarily mounted adjacent said table, a cam follower member operatively connected to said belt-supporting member and adapted to engage said cams as said table rotates for causing such relative movement, an endless polishing belt carried on said supporting member, means operatively connected to said belt for driving said belt, and 10 means engaging the inside surface of said belt for urging said belt into engagement with the side of the worm thread.

HAROLD V. CHRISTENSEN.