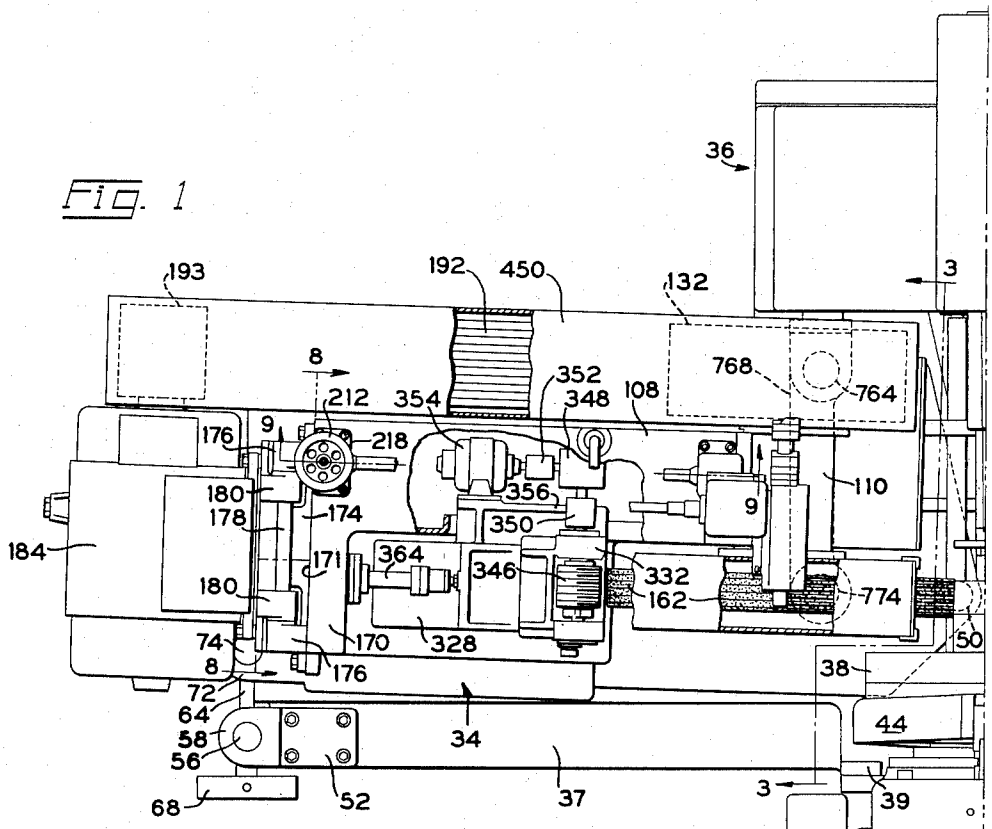
Nov. 27, 1951 C. A. REIMSCHISSEL ET AL 2,576,239

TUBE THREAD GRINDING MACHINE

Filed May 29, 1947 13 Sheets-Sheet 1

Fig. 1



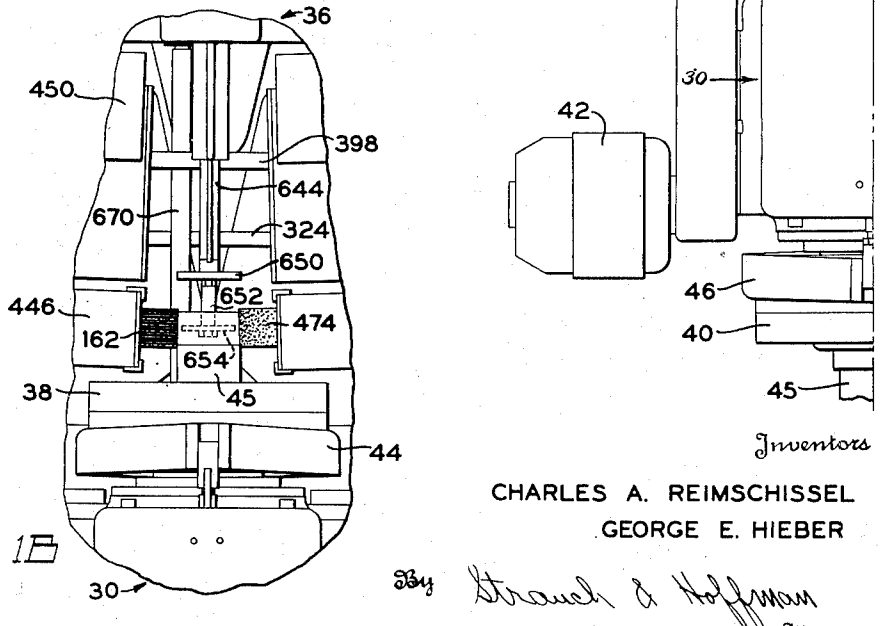


Fig. 1B

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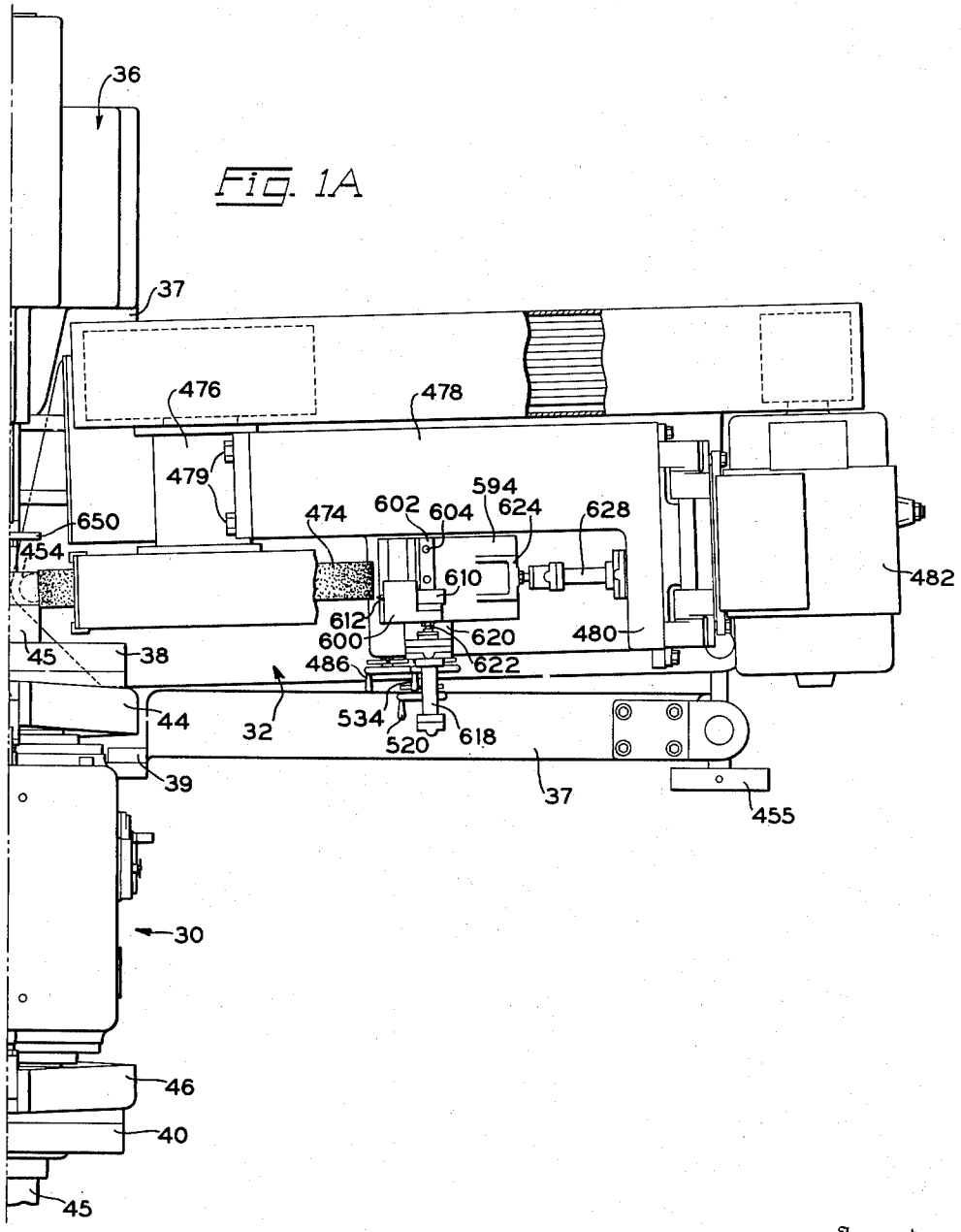
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TUBE THREAD GRINDING MACHINE

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Fig. 1A



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TUBE THREAD GRINDING MACHINE

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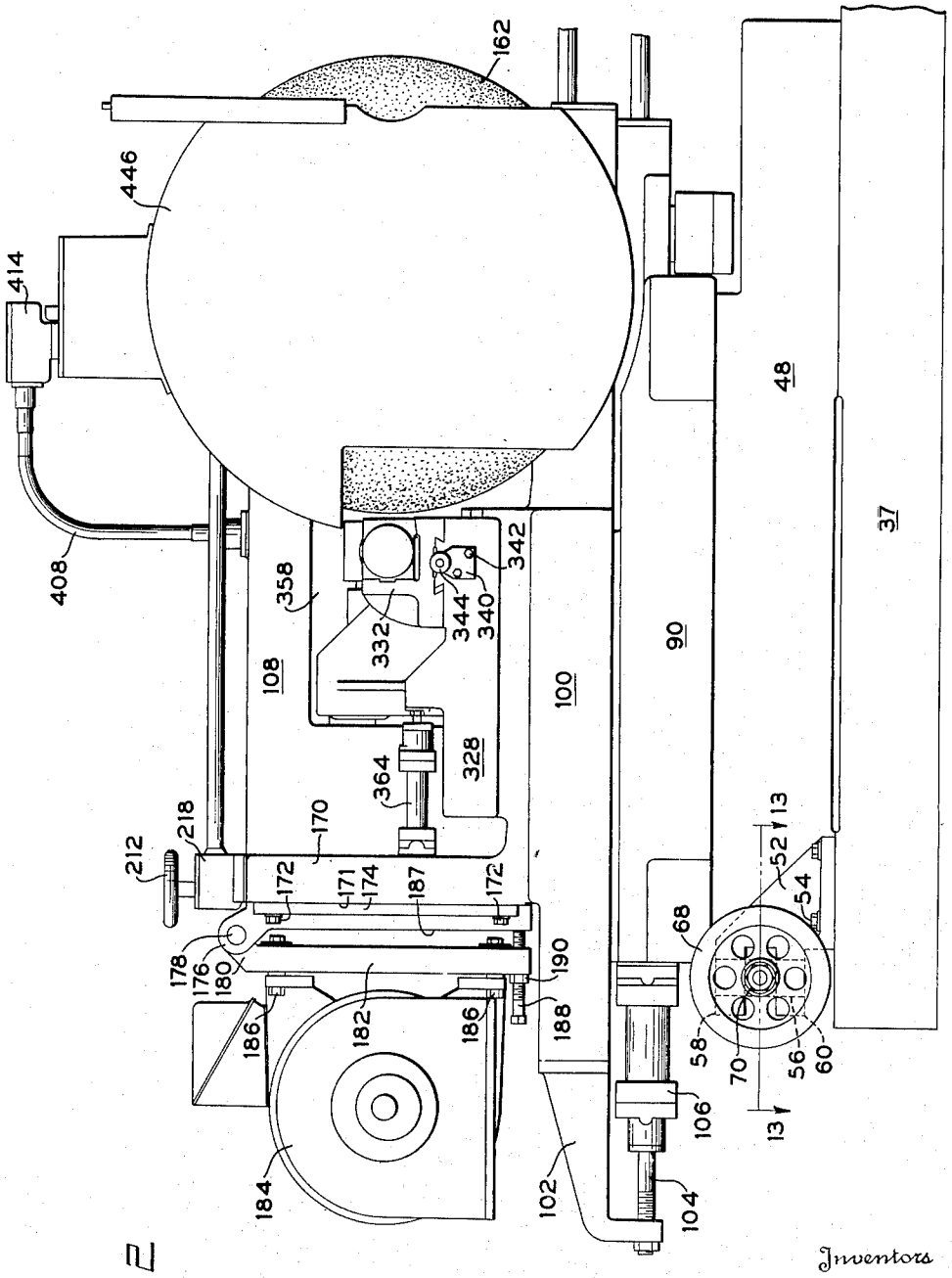


FIG. 2

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TUBE THREAD GRINDING MACHINE

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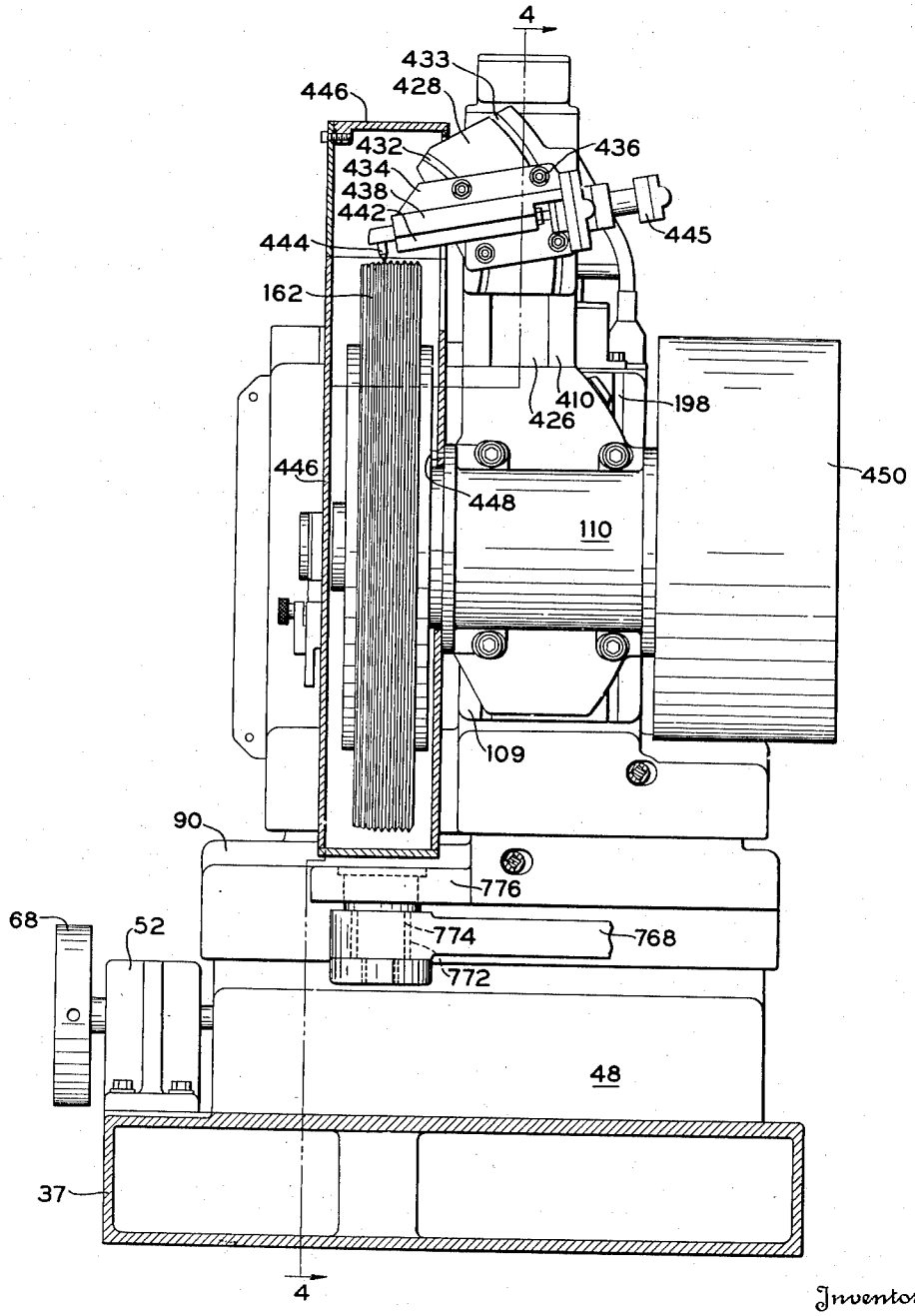


Fig. 3

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TUBE THREAD GRINDING MACHINE

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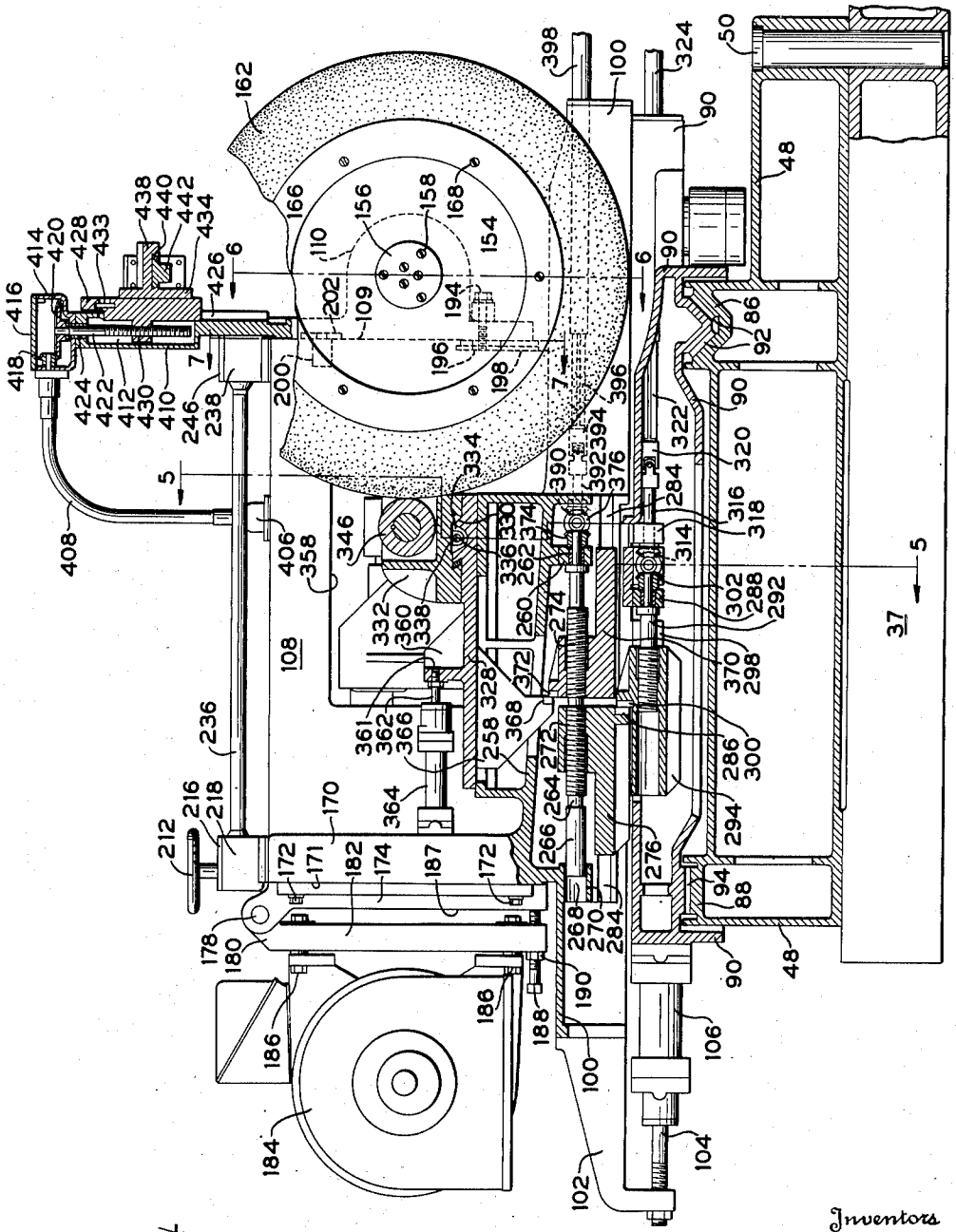


FIG. 4

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TUBE THREAD GRINDING MACHINE

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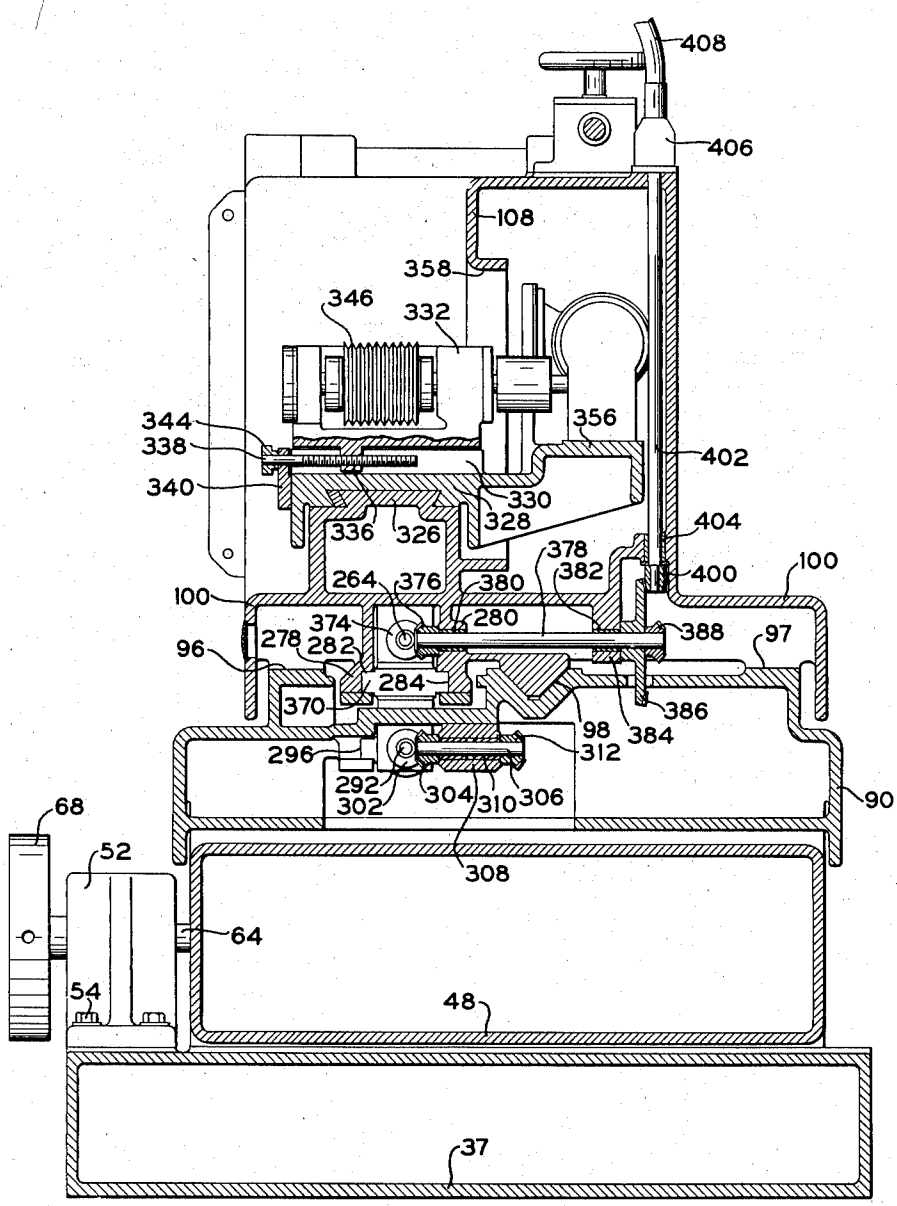


Fig. 5

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TUBE THREAD GRINDING MACHINE

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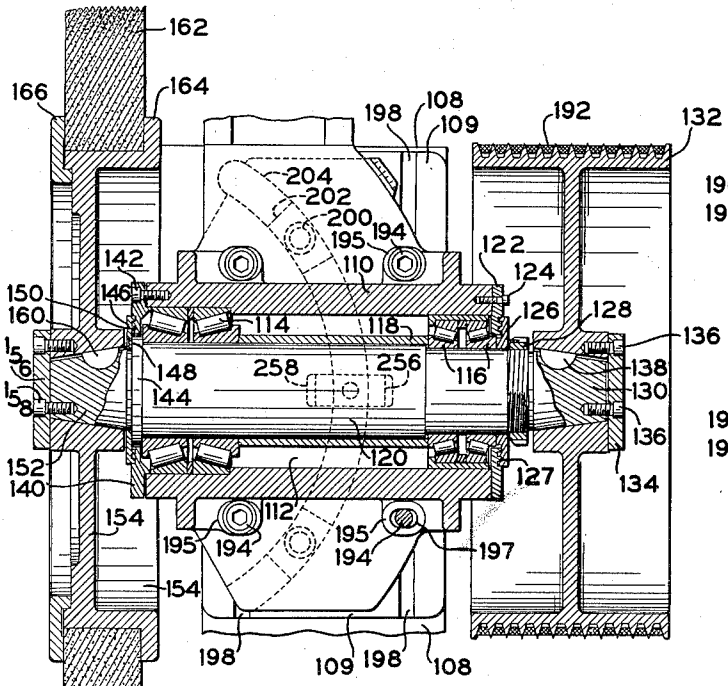


Fig. 6

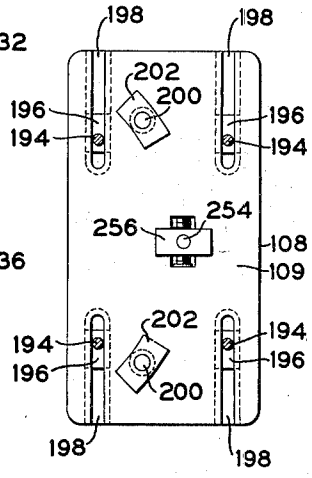


Fig. 7

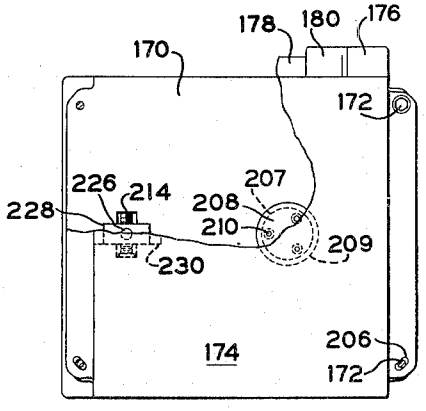


Fig. 8

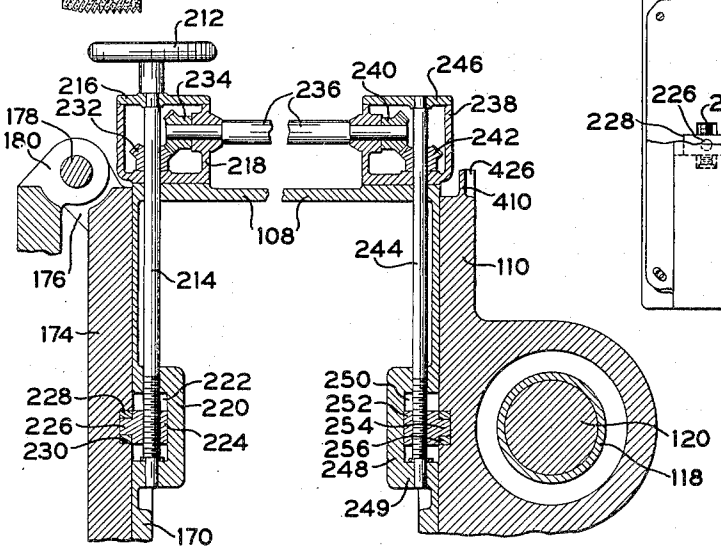


Fig. 9

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TUBE THREAD GRINDING MACHINE

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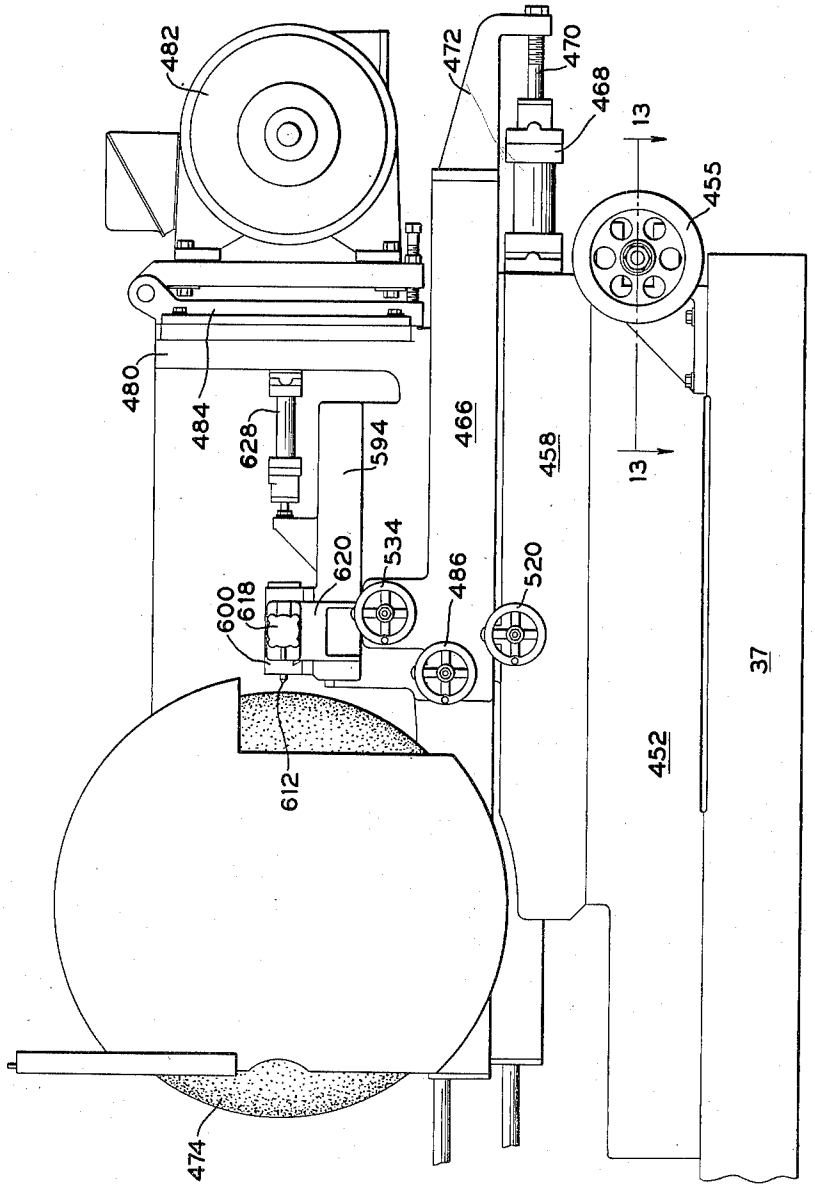


Fig. 10

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TUBE THREAD GRINDING MACHINE

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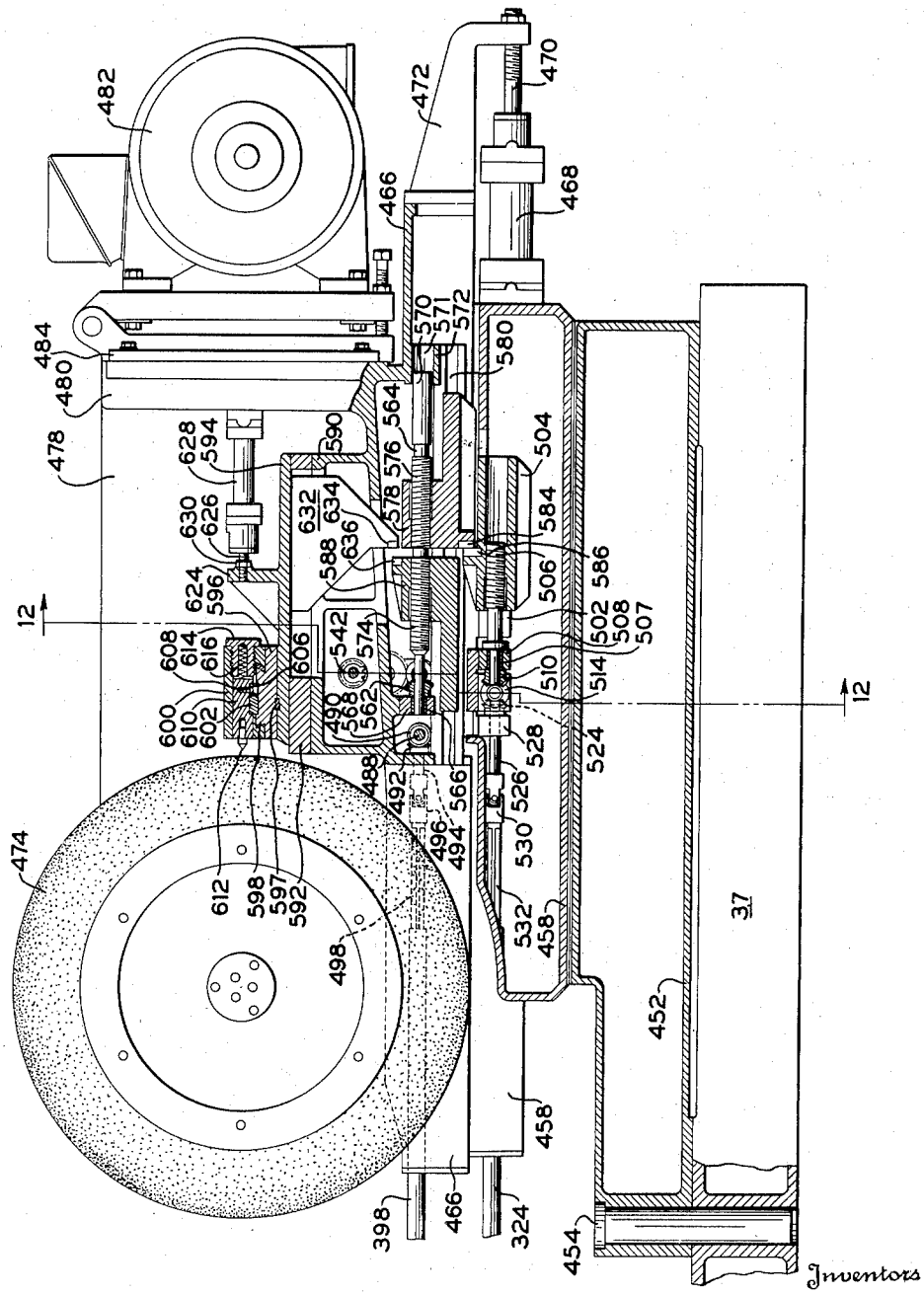


FIG. 11

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TUBE THREAD GRINDING MACHINE

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Fig. 12

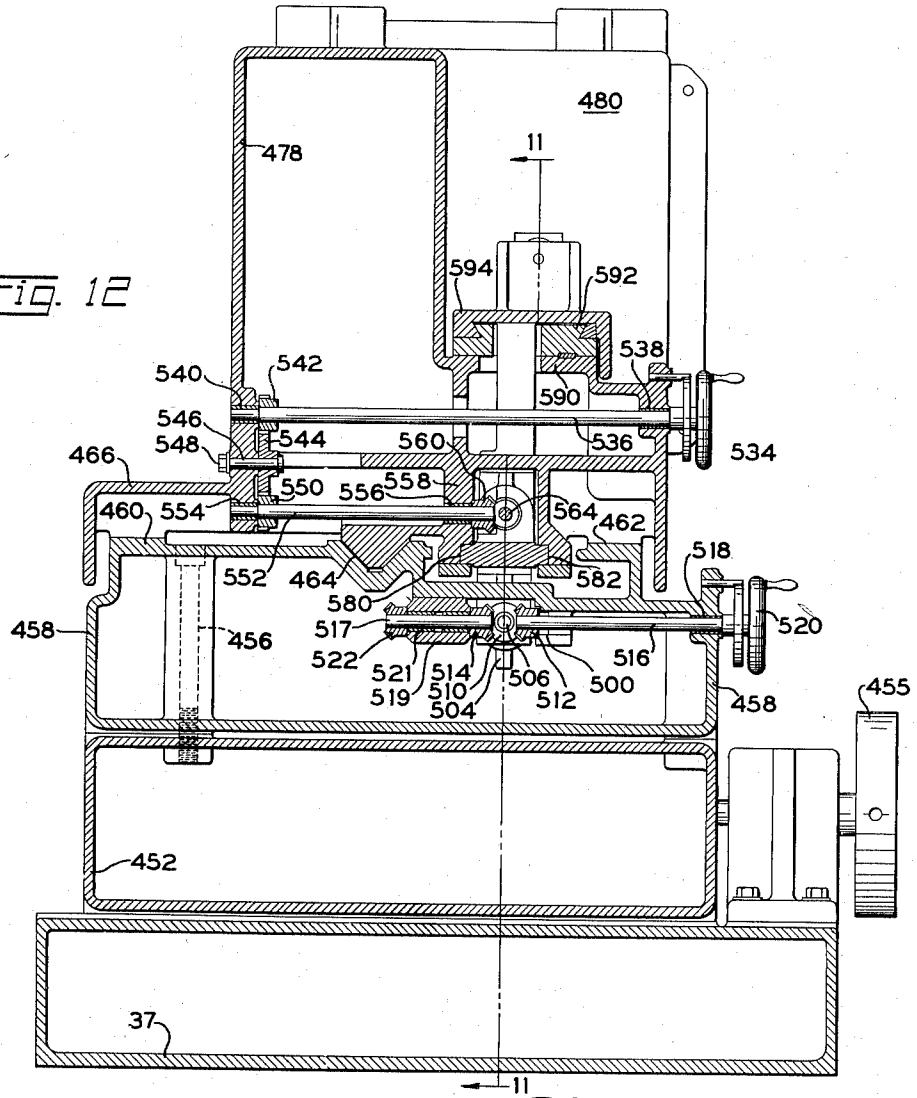


Fig. 13

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TUBE THREAD GRINDING MACHINE

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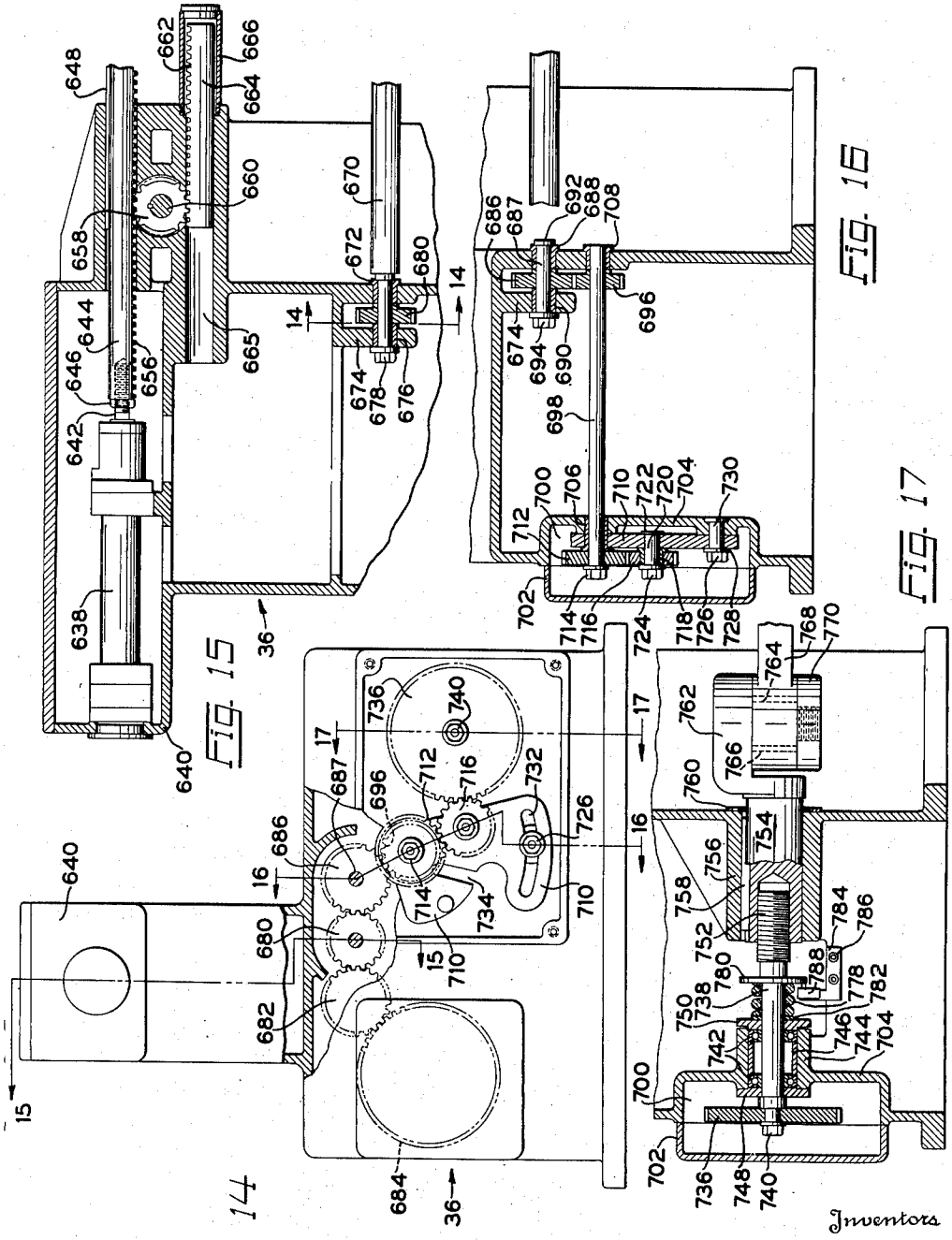


Fig. 14

Fig. 15

Fig. 16

Fig. 17

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TUBE THREAD GRINDING MACHINE

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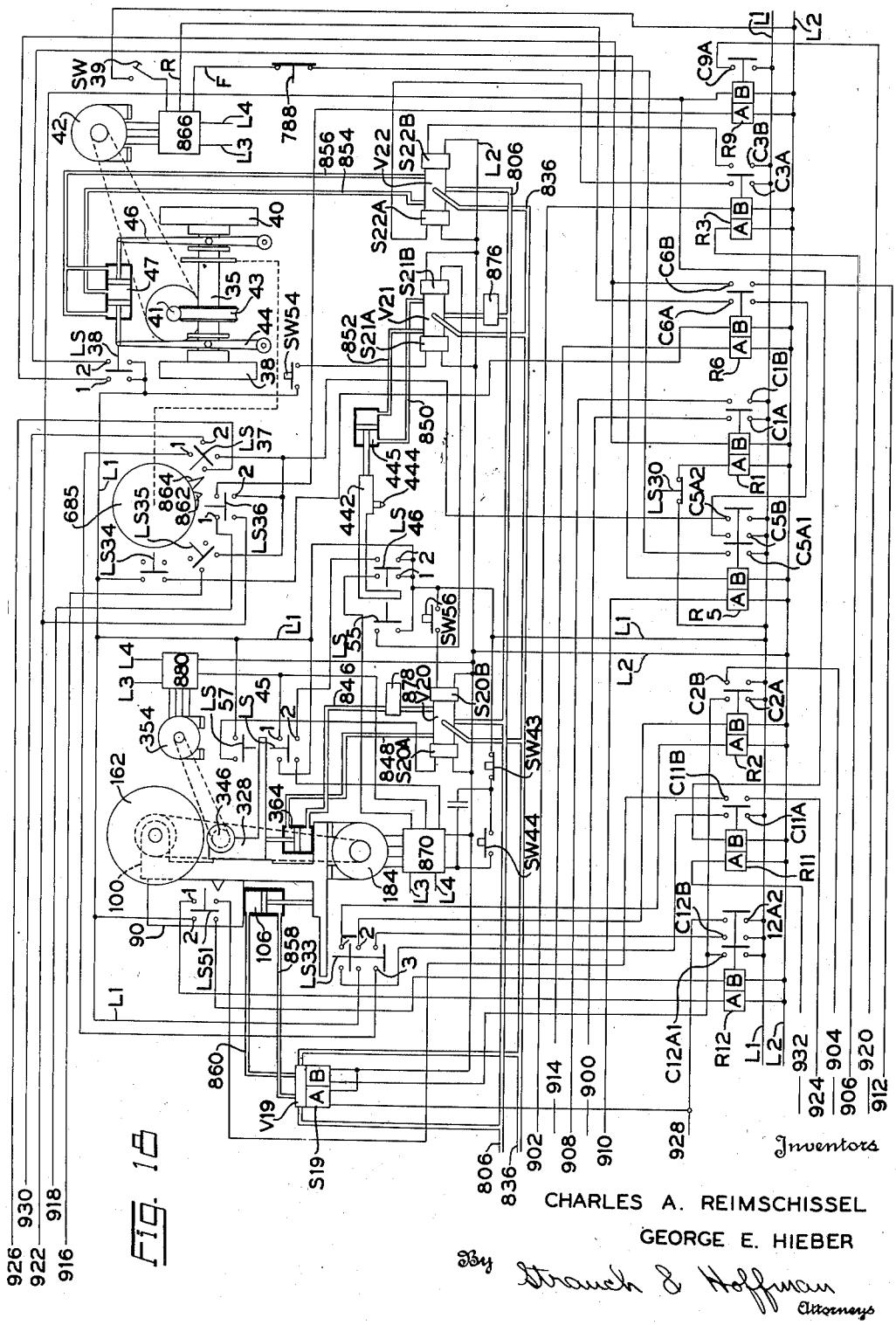


Fig. 18

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TUBE THREAD GRINDING MACHINE

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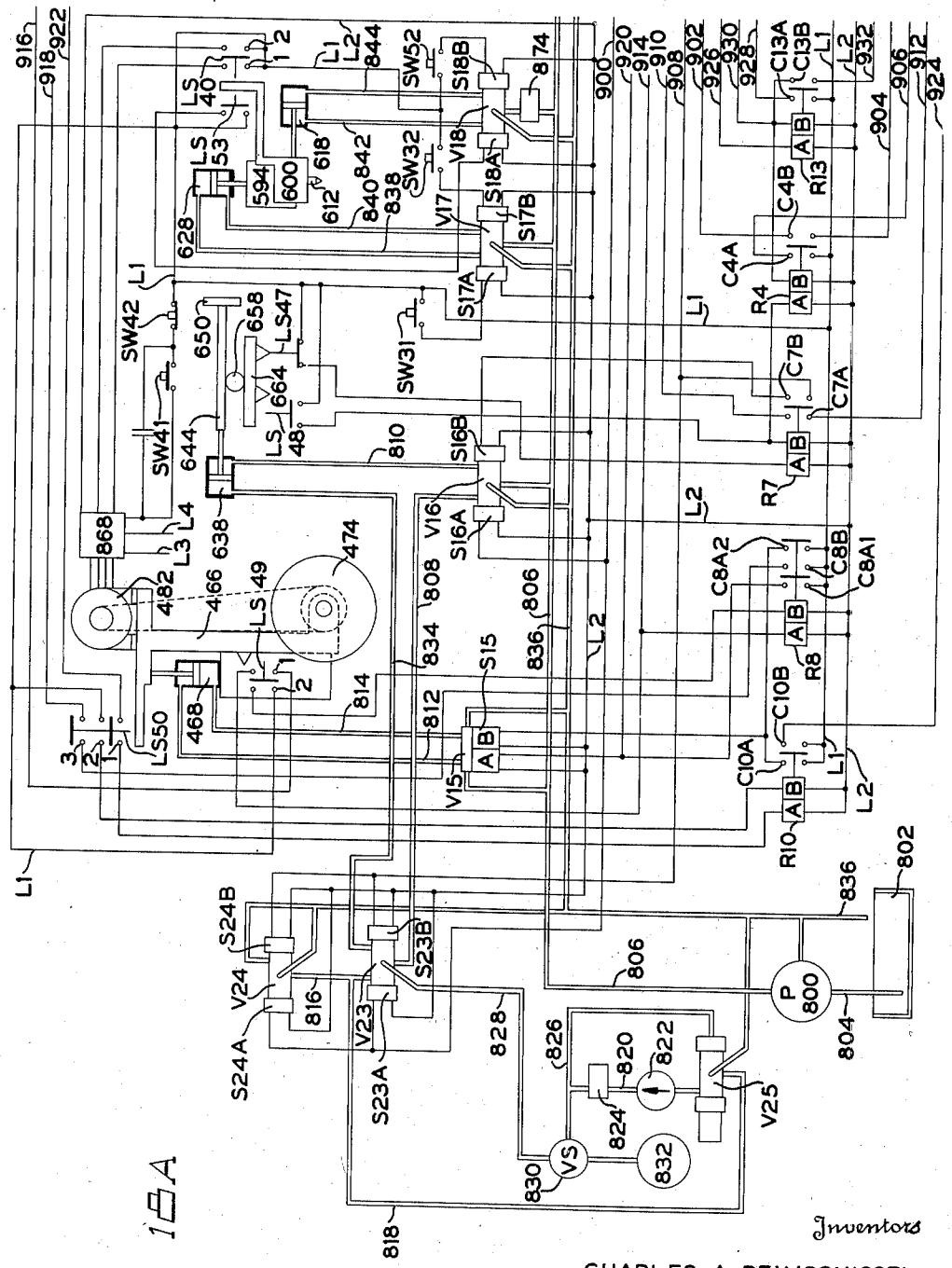


FIG. 18A

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Patented Nov. 27, 1951

2,576,239

UNITED STATES PATENT OFFICE

2,576,239

TUBE THREAD GRINDING MACHINE

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Application May 29, 1947, Serial No. 751,402

23 Claims. (Cl. 51—3)

1

This invention relates to machines for abrading metal and, more particularly, to a machine for automatically successively grinding contours, including threads, upon the exterior surfaces of pipe, tubing, and the like.

The present invention embraces numerous advances over the prior art. The steady trend, especially in the petroleum industry, to the use of pipe having greater strength and consequently less advantageous machining characteristics, reduces the effectiveness of the present method of forming the threads, etc., by cutting away the metal by the use of high speed tool steel cutters. The high-tensile alloy steels now used in the manufacture of much of the pipe used by the petroleum industry require such a low cutting speed as to render that method of machining relatively uneconomical.

The provision, in the present invention, for automatic and sequential grinding of the desired taper and thread on the pipe enables the production of pipe ends of improved accuracy and finish at a much faster rate than is possible when using a metal cutting operation.

Accordingly, it is an object of the invention to provide a machine for grinding first a tapered end and then a length of thread upon a pipe without transferring the pipe between operations. In the broader sense, it is possible, as will later be shown in detail, to perform two successive forming operations of various character. Such unusual operations are occasionally necessary as in the case of a tubing joint requiring two lengths of threads on the same end of the tube and having a sealing surface therebetween.

It is a further object of the invention to provide, in one machine, separate grinding mechanisms for performing preliminary and finishing operations upon a work piece, so that the preliminary operation, for instance taper forming, is performed by one grinding wheel, and the threading operation is performed by another.

Another object of the invention is the provision of ingenious mechanism to compensate for the change in grinding wheel diameter due to the dressing operation, so that the working position of the wheel periphery is not affected by such change.

A further object is to provide novel means for combining the adjustment of both grinding wheels relative to the work, so that a change in the working position of the grinding wheels, necessitated by a change in the work diameter, may be quickly and accurately made.

Another object is the provision of convenient

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and efficient wheel dressing mechanisms of the proper type for both the grinding wheels.

Another object is the provision of a novel machine for automatically performing sequential grinding operations upon a work piece which has been inserted into the machine.

Still other objects are to provide for the adjustment of the machine for various work diameters, tapers, thread lengths and helix angles, as well as to provide a machine which may be operated entirely automatically, once said adjustments are made.

Various other objects and advantages will be apparent from reference to the following description of a preferred embodiment of the invention and the accompanying drawings thereof.

In the drawings:

Figures 1 and 1A comprise a plan view of the entire machine;

Figure 1B is a partial plan view of that portion of the machine adjacent its centerline;

Figure 2 is a side elevation of the thread grinding wheel head;

Figure 3 is an elevation of the thread grinding wheel head taken substantially along line 3—3 of Figure 1;

Figure 4 is a longitudinal sectional view of the thread grinding wheel head taken substantially along line 4—4 of Figure 3;

Figure 5 is a transverse sectional view of the thread grinding wheel head taken substantially along line 5—5 of Figure 4;

Figure 6 is a fragmentary vertical sectional view on line 6—6 of Figure 4;

Figure 7 is a fragmentary vertical section on line 7—7 of Figure 4;

Figure 8 is a fragmentary vertical section on line 8—8 of Figure 1;

Figure 9 is a fragmentary vertical section on line 9—9 of Figure 1;

Figure 10 is a side elevation of the taper grinding wheel head;

Figure 11 is a longitudinal sectional view of the taper grinding wheel head taken substantially along line 11—11 of Figure 12;

Figure 12 is a transverse sectional view of the taper grinding wheel head taken substantially along line 12—12 of Figure 11;

Figure 13 is a fragmentary horizontal section on line 13—13 of Figure 2; and also shows the details of elements which would be seen in a section on line 13—13 of Figure 10, which elements would however appear reversed from their position in Figure 13, as will be understood;

Figure 14 is a rear end elevation of the stock

stop and leadscrew housing, having the gear box cover removed and being partially in section on line 14—14 of Figure 15;

Figure 15 is a vertical sectional view of the stock stop and leadscrew housing on line 15—15 of Figure 14;

Figure 16 is a vertical sectional view of the leadscrew mechanism on line 16—16 of Figure 14, detail beyond the plane of the section being omitted for purposes of clarity;

Figure 17 is a vertical sectional view of the leadscrew mechanism on line 17—17 of Figure 14, detail beyond the plane of section being omitted for purposes of clarity; and

Figures 18 and 18A taken together are a diagram of the electric circuit and hydraulic system which are interconnected to automatically operate the machine.

As seen in Figures 1 and 1A, the main divisions of the machine are the headstock 30, the taper grinding mechanism 32, the thread grinding mechanism 34 and the housing 36 containing the leadscrew and mechanism for regulating the axial position of the pipe to be machined. It will be noted that the taper grinding mechanism 32, the thread grinding mechanism 34 and the stock stop and leadscrew housing 36 are mounted upon a stationary base 37 which is secured at 39 to the headstock 30. The base 37 may be an integral structure or, for convenience of manufacture, it may be subdivided into a number of sections, secured together by bolts or the like.

The headstock 30 may be of a type now known to those skilled in the art having front and rear chucks 38 and 40 respectively for gripping the pipe. Chucks 38 and 40 are mounted upon opposite ends of a rotatable spindle 35 (Figure 18) which is driven through a worm 41 and a worm wheel 43 by a reversible direct current motor 42. Chucks 38 and 40 are opened and closed by yokes 44 and 46 respectively which are operated by a fluid cylinder 47 (Figure 18) contained in the headstock 30.

The above-described mechanism thus serves to support and rotate the pipe (indicated at 45) accurately about a constant axis and at a desired speed so that metal removing operations may be performed upon it. The detailed construction of said mechanism forms no part of the present invention and will not be further described.

Thread grinding mechanism

Referring to Figures 2, 3 and 4, the base 37 directly supports the slide base 48. A pivot pin 50 (Figure 4) is journalled through suitable aligned openings in both base 37 and slide base 48. Thus slide base 48 may be swivelled on base 37 about the axis of pivot pin 50. As seen in Figure 13, a bracket 52 is secured to base 37 by screws 54, near the rearward end of said base 37 and laterally spaced from slide base 48.

A pin 56 is passed vertically through the two rearwardly extending arms 58, 60 (Figure 2) of the bracket 52. Pin 56 is provided with a transverse opening 62 between arms 58 and 60, through which the screw 64 is journalled for rotation. Axial movement of screw 64 in one direction is prevented by the shoulder 66 thereon which abuts the flattened side of pin 56. The opposite side of pin 56 is also flattened adjacent opening 62 to receive in abutting relation the hub of handwheel 68 which is secured against rotation on screw 64 by a suitable key, not shown, and against axial movement by the nut 70 (Figure 2) threaded upon the outer extremity of screw 64.

The slide base 48 is provided with a vertically spaced pair of lugs 72 (Figures 1 and 13) through which the pin 74 is journalled. The screw 64 is threadedly engaged in a transverse threaded hole 75 in pin 74 between the lugs 72. The above-described mechanism constitutes the means for rotating the slide base 48 about the pivot pin 50. The required degree of rotation is achieved by reading the cooperating pointer 76 (Figure 13), attached to the rearward wall of slide base 48, and scale 78 inscribed upon the adjacent top surface of base 37. A screw 80 (Figure 13) having threaded engagement with a suitable opening in base 37 passes through elongated slot 82 in lug 84, which is formed integrally with slide base 48, and when tightened, secures slide base 48 in adjusted angular position.

As will be more fully realized later, this swivelling motion of slide base 48 in a horizontal plane about pivot pin 50 is for the purpose of exactly aligning said base and all the mechanism carried thereby, including the grinding wheel, with the taper of the thread desired to be produced upon the pipe, as seen in Figure 1.

As seen in Figure 4, the slide base 48 is provided with a pair of transverse slideways 86 and 88 upon which is mounted the cross slide 90. Slideway 86 is V-shaped and provided with rollers 92. Slideway 88 is of the flat type and is provided with rollers 94. Rollers 92 and 94 serve to eliminate friction and insure the facile movement of cross slide 90 in a transverse direction, movement in the longitudinal direction being prevented by the V-shaped slideway 86.

Referring to Figure 5, cross slide 90 is provided on its top surface with the flat slideways 96 and 97 and the V-shaped slideway 98 arranged in the longitudinal direction. Upon these ways, the wheel slide 100 is mounted. A bracket 102 (Figures 2 and 4) is mounted upon the rear wall of wheel slide 100 and extends rearwardly therefrom to engage the piston rod 104 of an hydraulic cylinder 106 which is secured to the rear wall of the cross slide 90. Cylinder 106 is operable automatically to reciprocate the wheel slide 100 in a direction perpendicular to the direction of movement of the cross slide 90. The manner in which such automatic operation may be accomplished will be described later.

The wheel slide 100 has along one side thereof the integral upward extension 108 (Figures 1, 2 and 4). To the centrally facing wall 109 (Figure 4) of extension 108 is secured, in a manner to be described later, the spindle housing 110, (Figure 6). A cylindrical opening 112 (Figure 6) through housing 110 contains, at opposite ends thereof, the bearings 114 and 116, axially spaced apart by means of the spacing sleeve 118. The wheel spindle 120 is thus rotatably supported by bearings 114 and 116.

At one end of the opening 112, bearings 116 are axially retained therein by the stationary cap 122 which abuts the outer race and is secured by screws 124 to the housing 110, and by the rotating cap 126 which is frictionally held between the inner bearing race and a lock nut 128 threadedly engaged on spindle 120. Caps 122 and 126 have interfitting ridges and grooves as at 127 to provide an effective end seal. The tapered extremity 130 of spindle 120 supports the V-belt sheave 132 which is retained in position axially by the cap 134 and screws 136. A key 138 insures unitary rotation of sheave 132 and spindle 120.

At the opposite end of opening 112, the bearings 114 are retained therein by the stationary cap 140, which abuts the outer bearing race and is secured to spindle housing 110 by means of screws 142, and by a shoulder 144 which is formed integrally with spindle 120 and which abuts the inner race. A rotating cap 146 is secured by means of screws 148 or the like to shoulder 144 and provides an end seal by having, together with cap 140, interfitting ridges and grooves 150. The tapered end 152 of spindle 120 supports the flanged grinding wheel hub 154 which is retained thereon by means of the cap 156 and screws 158. A key 160 prevents independent rotation of hub 154 and spindle 120. The thread grinding wheel 162 is axially retained on hub 154 by the integral flange 164 on one side and the plate 166 on the other side. Screws 168 secure plate 166 to hub 154 and clamp the wheel 162 against flange 164.

Wheel slide 100 is formed with an integral upward extension 170 (Figure 2) along its rearward end. Extension 170 is provided with a plane rear face 171 to which is secured by screws 172 the swivel plate 174. Lugs 176 (Figure 1) at each end of the top of plate 174 support the rod 178 which is also journalled through the lugs 180 which are formed integrally with the motor plate 182. A motor 184 is attached to motor plate 182 as by means of bolts 186. A set screw 188 is threaded into the bottom of the motor plate 182, passing therethrough to engage the rear surface 187 of swivel plate 174. A nut 190 retains screw 188 in adjusted axial position. Thus, by rotating motor 184 slightly about rod 178, by means of screw 188, the distance between the motor axis and the grinding wheel axis may be varied, providing a means for adjusting the tension of the driving belts 192 which connect the wheel sheave 132 and the motor sheave 193 which is mounted on the motor shaft.

The mounting of the swivel plate 174 and the spindle housing 110 at opposite ends of the wheel slide 100 is shown in Figure 4 and Figures 6 to 9 inclusive. The spindle housing 110 is secured to the forward vertical wall 109 of extension 108 by means of four screws 194 each of which threadedly engages a block 196 of T-shaped cross-section. The T-slots 198 formed in the face 109 of extension 108 prevent the blocks 196 from moving axially and thus the spindle housing 110 is firmly secured to extension 108. Bosses 195 on housing 110 have horizontally elongated openings 197 therethrough, for the passage of the screws 194. Thus when screws 194 are loosened, spindle housing 110 may be rotated in a vertical plane, as will be described.

A pair of pins 200 (Figures 4, 6 and 7) are embedded in extension 108 and protrude therefrom to thereby fasten the arcuately formed shoes 202 to the face 109. The shoes 202 are received in a shallow arcuate groove 204 lying in a vertical plane and formed in the rearward surface of housing 110. The center from which groove 204 is formed lies in a horizontal plane containing the grinding wheel axis and in a transverse vertical plane bisecting the grinding wheel 162. It is evident therefore that the screws 194 may be loosened and the spindle housing 110 and all mechanism supported thereby may be rotated in a vertical plane about a horizontal line bisecting the grinding wheel and passing through its axis.

The above described adjustment is for the purpose of tilting the grinding wheel 162 into alignment with the predetermined helix angle of the thread to be produced and is similar to the adjustment therefor disclosed in the co-pending application of Mr. Clarence B. Ziegler, Serial No. 519,210, filed January 21, 1944, now Patent No. 2,557,166, dated January 19, 1951.

To drive the grinding wheel spindle 120 without twisting the belts 192 as the housing 110 is rotated, a similar adjustment is provided for the motor 184. The screws 172 which secure swivel plate 174 to extension 170 pass through elongated slots 206 (Figure 8) therein, which permit rotation of plate 174 in a vertical plane. A pivot member 208 formed cylindrically with two diameters 207 and 209 has its larger diameter portion 209 extending into plate 174 and is secured thereto by screws 210. The smaller diameter portion 207 of pivot member 208 is free to rotate in a suitable mating opening in extension 170 as shown in Figure 8. The center of pivot member 208 lies in the horizontal line about which housing 110 is rotatable. Thus, when screws 172 are loosened, swivel plate 174 and all parts attached thereto may be rotated to the desired angle, keeping the two belt sheaves 132 and 193 in accurate alignment.

The mechanism for rotating the swivel plate 174 and spindle housing 110 in unison is best shown in Figure 9. The handwheel 212 is secured to the top of the vertical shaft 214, which is journalled through the cover 216 of the gear box 218 which is mounted on wheel slide 100 at the juncture of extensions 108 and 170 (Figures 1 and 2). Shaft 214 extends downwardly through the interior of extension 170 and has its lower end journalled through the lower arm of a U-shaped bracket 220 formed integrally with the rear wall of extension 170. A recess 222 is formed in the rear wall of extension 170 by the U-shape of the integral bracket 220. That portion of shaft 214 which passes through the recess 222 is threaded to engage thereon the travelling nut 224. Nut 224 is provided with a cylindrical projection 226 which extends outwardly from the surface of extension 170 to be pivotally received in a mating opening in the rectangular sliding block 228, which is free to move laterally in a slot 230 in the forward surface of plate 174. Thus, after screws 172 are loosened, the vertical movement of nut 224, caused by manual rotation of handwheel 212, will cause plate 174 and the motor attached thereto to rotate about the pivot member 208.

The gear box 218 contains the bevel gear 232, fixed to the shaft 214 for rotation therewith. A mating bevel gear 234 is similarly fixed to shaft 236 which is journalled through the side of gear box 218 and which extends through the side of a similar gear box 238 at the forward end of extension 108. Within gear box 238, the bevel gear 240 is fixed on shaft 236 to mate with bevel gear 242 which is fixed to the vertical shaft 244. Shaft 244 is journalled in the cover 246 of gear box 238 and in the lower arm 249 of a U-shaped bracket 248 formed integrally with the forward wall of extension 108.

A recess 250 in the forward wall 109 of extension 108 is formed and enclosed by the integral bracket 248. That portion of shaft 244 which passes through the recess 250 is threaded to engage thereon the travelling nut 252. Nut 252 is provided with a cylindrical projection 254 which extends outwardly from the surface of wall 109 to be pivotally received in a mating opening in the rectangular sliding block 256, which is free to move laterally in a slot 258 in the rearward surface of spindle housing 110. Thus when screws

194 are loosened the vertical movement of nut 252, caused by manual rotation of handwheel 212, will raise or lower the sliding block 256 and cause housing 110 and the parts supported thereby to rotate about the center of groove 204. It will be seen, therefore, that the angular adjustment of grinding wheel 162 and wheel motor 184 are synchronized and are effected by the same member, i. e., handwheel 212.

Referring to Figures 4 and 5, a web 258 slightly inclined to the horizontal is formed in the interior of wheel slide 100. Near its forward edge, web 258 is provided with a depending lug 260 which may be formed integrally therewith or as a separate member secured thereto. Journalled through the bushing 262 frictionally fitted in lug 260, the shaft 264 extends rearwardly therefrom and is provided at its rearward extremity with a guide portion 266 which is journalled for rotation in a suitable opening 268 in the lug 270 formed integrally with wheel slide 100. On shaft 264 and between guide portion 266 and lug 260 are formed two threaded portions 272 and 274 having threads of opposite hand.

Threadedly engaged on the rearward threaded portion 272 of shaft 264 is the bracket 276. As best seen in Figure 5, two vertically disposed webs 278, 280 are formed integral with wheel slide 100 and are arranged one on each side of the travelling bracket 276. Rectangular slideways 282 and 284 formed in the oppositely disposed surfaces of webs 278 and 280 respectively serve to support bracket 276. Across the lower portion of its forward surface, bracket 276 is provided with the hardened plate 286.

The cross slide 90 is formed interiorly with a lug 288 (Figure 4) which also may be formed individually and secured to cross slide 90. A short shaft 292 is journalled for rotation in lug 288 with its axis parallel to shaft 264. The travelling bracket 294 is threadedly engaged upon the threaded rearward extremity of shaft 292. Oppositely disposed rectangular slideways 296 and 298 (296 being visible in Figure 5 and 298 being visible in Figure 4) are also formed integrally with the frame of cross slide 90 to serve as support for the bracket 294. A hardened plate 300 is also attached to bracket 294, but on the upper side and facing in the direction opposite that of plate 286.

It will now be seen that, since cross-slide 90 has no movement in the direction perpendicular to the grinding wheel axis, bracket 294 will remain stationary in that direction until adjusted differently by rotation of shaft 292. It will also be apparent that, since the usual path of motion of the wheel slide 100 is perpendicular to the grinding wheel axis in order to bring the grinding wheel into contact with the work, bracket 276 will have motion in the said direction and that the depth of penetration of the grinding wheel into the work will be limited by the contact of plate 286 with stationary plate 300. When greater or less travel of wheel slide 100 is desired, as when a different size of work is operated upon, it is merely necessary to rotate shaft 292, thus moving bracket 294 farther from or closer to the center of the work and thus correspondingly decreasing or increasing the travel of the wheel slide 100.

Forwardly of the lug 288, on the extremity of shaft 292 is fixedly mounted the bevel gear 302 which (Figure 5) meshes with the bevel gear 304 secured upon the end of the transversely directed shaft 306. The separable lug 308, which is attached to the frame of cross slide 90, supports the bearing bushings 310 through which shaft 306 is journalled, another bevel gear 312 being affixed to the opposite end of shaft 306.

Gear 312 meshes with the bevel gear 314 (Figure 4) which is affixed to the longitudinal shaft 316, rotatably journalled in the lug 318, which is also secured to the frame of cross slide 90. A universal joint 320 on the opposite end of shaft 316 is connected to the spline shaft 322. A coupling 324 is telescoped over spline shaft 322 and is rotated by means of a handwheel 520 (Figure 10) as will be described later. It is obvious that this rotation will be properly transmitted regardless of the relative lateral or transverse position of the taper grinding mechanism and thread grinding mechanism due to the provision of the universal joint 320 and spline shaft 322.

Referring again to Figure 5, the wheel slide 100 is provided, rearwardly adjacent the grinding wheel 162 with the male element 326 of a dovetail slide, upon which is mounted the crusher slide 328 for reciprocating motion in a direction parallel to that of the wheel slide 100. The upper surface of the crusher slide 328 is also formed with the male element 330 of a dovetail slide, upon which the crusher bracket 332 is mounted for movement transversely of the crusher slide 328 and parallel to the grinding wheel axis.

A groove 334 longitudinally formed in the male element 330 provides space to receive a lug 336 formed on the bottom surface of the crusher bracket 332. A threaded shaft 338 is supported and journalled for rotation by the bracket 340 to extend interiorly of groove 334 and to engage the interiorly threaded lug 336. The bracket 340 is secured to the side of crusher slide 328 by the screws 342 (Figure 2). A knob 344 is affixed to the outer end of the threaded shaft 338 for rotating the same by hand and thereby causing the crusher bracket 332 to be adjusted transversely of the wheel slide 100 and the crusher slide 328.

Crusher bracket 332 supports the crusher roller 346, preferably made of hardened steel and used for renewing the desired contour of the grinding wheel 162. As is known in the art, the reverse of the desired contour is formed upon the roller 346 which is then forced radially against the periphery of the grinding wheel to impress the correct form into the relatively softer abrasive material thereof, both crusher roller and grinding wheel being rotated at slow identical surface speeds so that there is no relative surface movement therebetween.

The roller 346 is shown as driven through speed reducer 348 (Figure 1) and couplings 350 and 352, by motor 354. These latter units are all mounted on the sidewardly extending wing 356 of crusher slide 328. An opening 358 is provided in the side of extension 108 for the reception of these parts (Figures 2, 4 and 5).

That part of the crusher slide 328, which is rearwardly spaced from bracket 332, is provided with an integral upwardly extending bracket 360 (Figure 4). Into a threaded opening 361 in bracket 360 is threaded the piston rod 362 of the hydraulic cylinder 364, which is attached to the forward wall of the wheel slide extension 170. Thereby a means is provided for forcing the crusher slide 328 and roller 346 into contact with the grinding wheel and for withdrawing the same therefrom.

In Figure 4 it will be noted that crusher slide 328 is formed with a large downward extension

366 which extends through openings in dovetail 326 and web 258 into a position upwardly spaced from threaded shaft 264. A hardened block 368 is secured to the lower forward end of extension 366.

The forward threaded portion 274 of the shaft 264 is passed through the nut section of a sliding bracket 370, which, like bracket 276, is seated for sliding movement in the slideways 282 and 284. A hardened block 372 is attached to the rear top of bracket 370, in opposed relation to block 368 on bracket 366. Thus, it will be seen that movement of crusher slide 328 towards the grinding wheel is ended by the contact of blocks 368 and 372.

A bevel gear 374 is fixed on the forward end of shaft 264 and forwardly of bearing lug 260. Gear 374 meshes with bevel gear 376 which is attached to the cross-shaft 378. Shaft 378 extends through a bearing bushing 380 in the vertical web 280 and through bearing bushing 382 in the aligned lug 384 (Figure 5). Two gears are mounted upon the other end of shaft 378 beyond the bearing 382: the large bevel gear 386 which is mounted adjacent bearing 382 and the smaller bevel gear 388 secured upon the extreme end of the shaft.

Bevel gear 388 cooperates with bevel gear 390 (Figure 4) which is connected by shaft 392, universal joint 394, and spline shaft 396 to the splined coupling 398, which is connected to be rotated by a crusher handwheel 486 in a manner to be later described.

Bevel gear 386 (Figure 5) engages the bevel pinion 400 which is secured to the lower end of the vertical shaft 402. Shaft 402 is journalled through the bearing bushing 404 fixed in the frame of wheel slide 100 and extends upwardly to the connector 406 mounted on top of the wheel slide extension 108 where shaft 402 is attached to the flexible shaft indicated at 408 (Figure 4).

Spindle housing 110 is provided with an upwardly extending bracket 410 (Figures 3 and 4) which is formed with a spacious recess 412 on one side. Secured to the top of bracket 410 is a gear box 414 having a cover 416. The extremity of flexible shaft 408 is journalled through the side of gear box 414 and has a bevel pinion 418 attached thereto. The mating bevel gear 420 is mounted on the upper end of the vertical shaft 422 which is journalled through the bushing 424 fixed in the bottom of gear box 414 and bracket 410.

Referring to Figures 3 and 4, the bracket 410 is provided, on one side thereof, with the dovetail slideway 426 in which is mounted for vertical sliding movement the dresser base 428. A lug 430 projects from the rearward surface of dresser base 428 into the recess 412. Shaft 422 is threadedly engaged with lug 430 so that rotation of shaft 422 will cause dresser base 428 to move vertically. The outer surface of dresser base 428 is provided with two laterally spaced arcuate T-slots 432, 433. The bracket 434 is adjustably secured to dresser base 428 by screws 436 and suitable T-clamps (not shown), engaging the slots 432 and 433.

A forward extension 438 of bracket 434 is formed, on its downwardly facing surface, with a dovetail slideway 440 in which is mounted for sliding movement the dresser slide 442. A diamond dressing tool 444 is held in operative relation to grinding wheel 162 by the slide 442. To the opposite end of bracket 434 a hydraulic cylinder 445 is attached having its piston rod secured to the rear end of dresser slide 442 making it possible to reciprocate dressing tool 444 across the face of grinding wheel 162.

It is apparent then that the working position of the dressing tool 444 is adjustable vertically for change in diameter of the grinding wheel by means of threaded shaft 422 and lug 430. The path of reciprocation of dressing tool 444 is adjustable angularly by means of the arcuate T-slots 432. Thus, as shown in Figure 3, the thread-forming grooves of grinding wheel 162 may be beveled off by dressing tool 444 at any desired angle with the axis of the wheel. This is useful to enable the wheel to reproduce on the work the gradual vanishing of the threads that present pipe thread standards demand.

In Figures 2 and 3 will be seen the conventional type of wheel guard 446 surrounding grinding wheel 162 and attached by screws 448 to spindle housing 110. A similar cover 450 is provided to envelop the belts and driving sheaves.

Taper grinding mechanism

This mechanism, as shown in Figures 10, 11 and 12, is provided for the purpose of preparing the pipe 45 for the threading operation by grinding the portion to be threaded to the desired conical form. The main machine base 37 supports the slide base 452 which is mounted thereon to swivel about the pivot pin 454 (Figures 1A and 11). The mechanism for regulating this movement is identical with that described previously as being associated with slide base 48, and is controlled by hand wheel 455. Secured to slide base 452 by screws 456 (Figure 12) is the stationary support member 458, corresponding to the cross slide 90 of the thread grinding mechanism. Since there is no necessity for movement of the taper grinding wheel in an axial direction, support member 458 is thus stationarily mounted upon slide-base 452.

Flat slideways 460 and 462 and V-shaped slideway 464 are provided on the top of support member 458 to enable the taper grinding wheel slide 466, mounted thereon, to reciprocate in a direction perpendicular to the grinding wheel axis. This motion is powered and controlled by the hydraulic cylinder 468 mounted on the rear wall of support member 458 and having its piston rod 470 connected to rearwardly extending bracket 472 attached to the rear wall of wheel slide 466.

The taper grinding wheel 474 is supported by the spindle housing 476 (Figure 1A) in the same manner that thread grinding wheel 162 is supported by spindle housing 110. In the present instance, however, spindle housing 476 is removably, but not adjustably, affixed to the forward wall of the upward side extension 478 of wheel slide 466, as by the cap screws 479 (Figure 1A), since the necessity for helix angle adjustment is not present in the taper grinding mechanism.

The wheel slide 466 is also provided with the upward extension 480 along the outboard or rearward end thereof. The taper grinding wheel motor 482 is mounted upon extension 480 in the same manner as the thread grinding wheel motor is mounted, with the exception that no provision is made for swiveling the plate member 484 relative to extension 480. The mechanism for transmitting power from motor 482 to grinding wheel 474 is identical to that described above for the thread grinding mechanism.

The crusher handwheel 486 (Figure 10) transmits motion through shaft 488 (Figure 11) to the bevel gear 490 (Figure 11). Gear 490 meshes with bevel gear 492 mounted upon shaft 494 which is

connected to universal joint 496, spline shaft 498 and splined coupling 398. Thus, through the above described connection and its continuation in the thread grinding mechanism, crusher handwheel 486 serves to rotate directly the shaft 264 (Figure 4) which moves the brackets 276 and 370 in opposite directions.

Referring to Figures 11 and 12, support member 458 is provided, interiorly thereof, with longitudinally directed, rectangular slideways 500 (Figure 12) and 502 (Figure 11) in which bracket 504 is mounted. A shaft 506 is journalled for rotation in bushing 507 in the detachable lug 508 which is secured to the frame of support member 458. One end of shaft 506 is threadedly engaged in the travelling bracket 504 while the opposite end has secured thereto the bevel gear 510.

Gear 510 meshes with two bevel gears 512 and 514 (Figure 12). Gear 512 is mounted upon shaft 516 which is journalled through bushing 518 in the side wall of support member 458. A handwheel 520 is secured to the outer end of shaft 516. Thus rotation of shaft 506 is produced and the same rotational movement is transmitted through gears 512, 510 and 514 to a coaxial shaft 517 to which gear 514 is attached. Shaft 517 is journalled through the bearing bushings 521 in the lug 519 secured to the frame of support member 458. The opposite end of shaft 517 has mounted thereon the bevel gear 522.

Gear 522 meshes with bevel gear 524 (Figure 11) which is secured upon shaft 526 journalled through lug 528 attached to the frame of support member 458. Shaft 526 is connected by universal joint 530 and spline shaft 532 to the splined coupling 324 for transmission of rotary movement through the mechanism previously described to shaft 292 (Figure 4) in the thread grinding mechanism. Thus it is apparent that handwheel 520 is employed to adjust brackets 294 and 504 simultaneously.

Another handwheel 534 is mounted upon a transverse shaft 536 which is journalled for rotation in the bearing bushing 538 set in the side wall of wheel slide 466. Shaft 536 extends through wheel slide 466 and has its opposite end journalled in bushing 540 fixed in the opposite wall of said wheel slide 466. Interiorly adjacent bushing 540 a pinion 542 is mounted on shaft 536 for engagement with an idler spur gear 544. A stud 546 which supports gear 544 is journalled through the side wall of wheel slide 466 and is held in correct axial position by the nut 548 engaged on the outer extremity thereof. Gear 544 meshes with pinion 550 to transmit rotary motion to shaft 552 on which pinion 550 is mounted. Shaft 552 is journalled for rotation in bushings 554 and 556 in the side wall of wheel slide 466 and the centrally disposed web 558 respectively. A bevel gear 560 mounted on the inner end of shaft 552 meshes with bevel gear 562 (Figure 11) secured on the longitudinal threaded shaft 564.

Shaft 564 has its forward end journalled for rotation in bushing 566 fixed in lug 568 which is secured to the frame of wheel slide 466. Extending rearwardly therefrom, shaft 564, terminates in a guide portion 570 which passes through an opening 571 in lug 572 formed integrally with wheel slide 466. Between portion 570 and gear 562, shaft 564 has two threaded portions 574 and 576, the threads of which are of opposite hands. The rearward threaded portion 576 engages the threaded bore of sliding bracket 578 which is mounted for longitudinal sliding movement in the rectangular slideways 580 and 582 formed integrally with wheel slide 466.

The forward threaded portion 574 of shaft 564 engages the threaded bore of the sliding bracket 588 which slides in the ways 580 and 582, in alignment with bracket 578. There is considerable clearance between the guide portion 570 on shaft 564 and the opening 571 because the purpose of the opening 571 is only to prevent shaft 564 from shifting out of proper alignment, it being journalled only in bushing 566 and its remainder being supported by being threaded through brackets 578 and 588.

A hardened plate 584 is carried by bracket 578 at its forward lower edge to engage a similar plate 586 carried at the top of bracket 504. Thus, the relative positions of brackets 504 and 578 determine the amount of infeed applied to grinding wheel 474, an amount which may be made greater, as when a smaller diameter work piece is being operated upon, by turning handwheel 520 to move bracket 504 to the left (Figure 11) and vice versa.

In Figures 11 and 12 it is seen that the wheel slide 466 is provided with a platform 590 upon which is mounted the male element 592 of a dovetail slide. A dresser slide 594 is mounted on male element 592 for reciprocation in a path perpendicular to the axis of grinding wheel 474. A plate 596 is mounted on the forward end of dresser slide 594 and is positioned by the key 597. The male element 598 of a dovetail slide in the transverse direction is formed on plate 596. A transverse slide 600 is slidably mounted on male element 598.

A template 602 is secured by screws 604 (Figure 1A) to plate 596. A template follower 606 is secured by screw 608 to the side of a substantially cylindrical member 610 journalled longitudinally through transverse slide 600. A diamond tool 612 is supported by member 610 and maintained thereby in correct position for dressing grinding wheel 474. A hollow member 614 is threadedly engaged in slide 600 in alignment with member 610 and contains a compression spring 616 which presses against member 610 and thereby maintains follower 606 in contact with template 602.

From Figures 1A and 10 it is seen that a hydraulic cylinder 618 is mounted upon a bracket 620 extending from the side of dresser slide 594. The piston rod 622 of cylinder 618 is attached to transverse slide 600 so that, by proper operation of said cylinder, diamond tool 612 is caused to reciprocate across the peripheral face of the grinding wheel 474.

An upright bracket 624 is formed integrally with dresser slide 594 to threadedly engage the piston rod 626 (Figure 11) of the hydraulic cylinder 628. A nut 630 locks piston rod 626 in desired axial position. Cylinder 628 is secured to the forward wall of extension 480 of wheel slide 466 and is effective to move diamond tool 612 into a position where it is ready to traverse the grinding wheel 474. The cylinder 628 is not essential to proper operation of this wheel dressing operation but may be used, if desired, to withdraw the diamond tool 612 from proximity to grinding wheel 474 for replacement or other reasons and for returning said tool to operative position without disturbing the previously adjusted relationship between dressing tool position and grinding wheel diameter.

In Figure 11 it will be noted that dresser slide 594 is provided with a downwardly extending

portion 632, to the lower forward extremity of which is attached a hard plate 634 in opposed relation to a similar plate 636 in the upper forward corner of bracket 588. Thus the forward motion of dresser slide 594 and, consequently, the amount of penetration of diamond tool 612 into grinding wheel 474 is limited by the position of bracket 588. This position, as before described, is adjustable by rotation of handwheel 634.

Auxiliary mechanisms

Figures 1 and 1A show the housing 36 located opposite the head stock 30 and partly between the taper and thread grinding mechanisms. This housing 36 and its contents are more fully shown in Figures 14 to 17 inclusive.

Figure 15 shows a hydraulic cylinder 638 mounted in the upward extension 640 of housing 36. The piston rod 642 of cylinder 638 is threadedly engaged in the rearward end of the rod 644. A lock nut 646 is provided for the purpose of maintaining this adjustable connection in adjustment, and a key 648 prevents rotation of rod 644 in the opening in extension 640 of housing 36 through which said rod is slidably journalled.

Figures 1 and 1A show that rod 644 extends from housing 36 toward the front chuck 38 in alignment with the center thereof. A stop bar 650 is secured to rod 644 for the purpose of engaging the end of the pipe 45 to be machined and placing said pipe in proper position between the grinding wheels as will be described. A further extension 652 (Figure 1B) of rod 644 carries a cylindrical sealing member 654 inside the pipe while it is being operated upon to prevent escape of coolant, etc. through the pipe.

Rod 644 is provided, along its lower surface, with the rack teeth 656. A gear 658 is fixed upon shaft 660 which is journalled for rotation in opposite walls of extension 640 of housing 36. Gear 658 acts to transmit longitudinal motion from rack teeth 656 to similar rack teeth 662 formed along the upper surface of a switch actuator rod 664 which is journalled for reciprocative longitudinal movement in a bore 665 in the extension 640. A tube 666 having its outer end closed is threaded into the outer end of the bore 665 to provide sufficient room for the travel of rod 664 and at the same time prevent the entry of foreign matter into the mechanism.

It will be seen that the movement of rods 644 and 664 will be controlled by the cylinder 638 and that said rods will always move in opposite directions. As will be explained later in connection with Figure 18A, the rod 644 carries a pair of dogs which operate a pair of limit switches LS47 and LS48.

A rotatable shaft 670 (Figures 1B and 15) extends from the headstock 30, where it is connected by means of suitable gearing (not shown) to the driving motor 42, to the housing 36, where it is journalled in bushing 672 in the forward wall thereof (Figure 15). A bracket 674 is formed integral with the frame of housing 36 and supports a bushing 676 in which shaft 670 is also journalled. A lock nut 678, threaded upon the end of shaft 670, retains the same in correct axial position.

In the space between bushings 672 and 676, a spur gear 680 is fixedly mounted on shaft 670. On one side, gear 680 drives the gears 682 and 684 (Figure 14), the latter of which is suitably connected to a timing mechanism 685 (Figure 18) whose purpose is to synchronize the operations of all parts of the machine. On the other side, gear 680 drives gear 686 (Figures 14 and 16) which is mounted on a stud 687 journalled in bushings 688 and 690 (Figure 16) in a housing 36 and bracket 674 respectively. The enlarged end 692 of stud 687 and a locknut 694 prevent axial movement of said stud.

Gear 686 drives gear 696 (Figures 14 and 16) fixed on shaft 698. The rear wall of housing 36 is provided with a large recess 700 to receive the leadscrew change gears of the machine. A cover 702 is removably secured over recess 700. The bottom wall 704 of recess 700 is bored to receive the bearing bushing 706. Shaft 698 is journalled for rotation in bushings 706 and 708, the latter of which is secured in the forward wall of housing 36.

Also pivoted about bushing 706 is a gear quadrant 710, exteriorly of which gear 712 is fixedly mounted upon shaft 698. A nut 714 is provided to retain shaft 698 in axial position. Gear 712 drives gear 716 which is rotatably mounted upon a bushing 718 supported by stud 720. Stud 720 passes through a suitable opening in gear quadrant 710 and is held in place axially by its own enlarged head 722 and nut 724 which is clamped against the bushing 718.

Gear quadrant 710 is secured in adjusted angular position about shaft 698 by the nut 726 and washer 728 which are received upon stud 730 mounted in an opening through wall 704 of recess 700. Stud 730 passes thorugh the arcuate slot 732 (Figure 14) in quadrant 710, which provides for its adjustment to any of a variety of angular positions according to the gear ratio selected. Another slot 734, having one end open, is provided in quadrant 710 for the insertion of a stud carrying another idler gear for the purpose of reversing the direction of the final driven gear and thus, as will be more evident later, cutting a left hand thread.

Gear 716 drives the leadscrew gear 736 (Figures 14 and 17) which is secured upon the rearward extremity of the leadscrew 738 by the nut 740. Leadscrew 738 is supported for rotation by bearings 742, 742 contained in the boss 744 formed in the bottom wall 704 of recess 700 but it may move axially with respect to them under overload conditions, as will be apparent. The bushing 746 is employed as a spacing member between bearings 742, 742. The caps 748 and 750 are provided at opposite ends of boss 744 surrounding leadscrew 738 to retain bearings 742, 742 in said boss, the caps being affixed to the boss in any suitable manner.

The threaded portion 752 of leadscrew 738 is engaged in the leadscrew nut 754 of cylindrical outline and journalled for longitudinal movement in the boss 756 in the forward wall of housing 36. A key 758 prevents rotation of leadscrew nut 754. A sealing member 760 surrounds leadscrew nut 754 on the outer side of boss 756. Exteriorly of housing 36, leadscrew nut 754 is formed with an integral arm 762 and pin 764 which pin is positioned vertically across the axis of leadscrew nut 754. A bearing bushing 766 surrounds pin 764 and has journalled thereon one end of a link 768. A locknut 770 is threadedly engaged on the end of pin 764 to retain link 768 thereon.

As seen in Figures 1 and 3, link 768 has its other end journalled upon bushing 772 which is fitted over the vertical pin 774. Pin 774 is fixed in the extension 776 of cross slide 90. Thus, it is apparent that rotation of the above-described lead-

screw gears rotates leadscrew 752 and causes leadscrew nut 754 to move axially. Link 768 is thus caused to move cross slide 90 along the ways 86 and 88 and generate the lead of the thread being ground. In the case of right hand threads which constitute a great majority of all tube threads, the axial motion of leadscrew nut 754 is to the right as seen in Figure 17 during the grinding operation.

An overload safety device is provided for the leadscrew mechanism by mounting a strong compression spring 778 on leadscrew 738 between the collar 780 thereon and the washer 782 adjacent cap 750. A bracket 784 secured by screws 786 to a convenient portion of housing 36 supports a limit switch 788 in operative position adjacent collar 780. Thus when cross slide 90 resists the force applied to it through link 768 and leadscrew nut 754, the leadscrew 738 may be moved axially to the left as seen in Figure 17. If the resistance of cross slide 90 is sufficient to compress spring 778, the resulting axial movement of leadscrew 738 causes collar 780 to operate limit switch 788 to stop the machine.

The operation of the crusher mechanism provided for the thread grinding wheel 162 may be in general similar to that described in the copending application of C. W. Hopkins et al., Serial No. 583,038 filed March 16, 1945. There is provided, however, a means for compensating the extent of thread grinding wheel infeed for the reduction in diameter of said wheel due to the dressing operation and similar compensating means, independently controlled, controls the advance of the taper grinding wheel in accordance with a reduction in its diameter after dressing.

Summary of adjustments

Referring to Figure 4, it will be remembered that the limit of the movement of the thread grinding wheel 162 into the work is controlled by the engagement between the plates 286 and 300 on brackets 276 and 294. The position of bracket 294 with its stop plate 300 is adjusted by handwheel 520. The purpose of this adjustment is to provide for work of various diameters since the thread grinding wheel will not travel as far towards the work axis when the work is of a large diameter as it will when the work is of smaller diameter. The same handwheel 520 simultaneously adjusts the bracket 504 in the taper grinding mechanism to position the stop plate 586 which limits the movement of the taper grinding wheel 474 into the work.

The grinding wheels 162 and 474 are not dressed except when it is determined that a dressing is needed, and both wheels do not usually require dressing at the same time. For the convenience of the operator the handwheel 486 which adjusts the dressing mechanism for the grinding wheel 162 is placed adjacent the handwheel 534 which adjusts the dressing mechanism for the grinding wheel 474, both these handwheels being adjacent the previously described handweel 520.

When dressing the thread grinding wheel 162 its slide 100 is in its retracted position and grinding wheel 162 is driven at a relatively slow speed so that its peripheral speed is the same as that of the crusher roller 346. Handwheel 486 is changed from its previous setting to the proper new setting for the dressing, by which operation the diameter of grinding wheel 162 will be slightly reduced. As viewed in Figure 4, this adjustment of handwheel 486 will move the stop plate 372 on bracket 370 slightly to the right so that the crusher roller 347 will penetrate slightly farther into the grinding wheel when actuated by cylinder 364 than it did during its last previous dressing operation. Bracket 276 will be simultaneously moved slightly to the left as viewed in Figure 4, so that during the next thread grinding operation the wheel slide 100 can move slightly farther to the right before its movement is stopped by engagement of plate 286 with stop plate 300. This further movement of wheel slide 100 compensates for the reduction in diameter of the grinding wheel 162, so that threads of full required depth will still be cut.

After the crusher roller has reached the limit of its movement it is left in contact with the grinding wheel for several revolutions and then withdrawn by the action of hydraulic cylinder 364. The hydraulic cylinder 445 is now actuated to reciprocate the diamond tool 444 across the outer face of the wheel and back to its starting position. When being dressed by the diamond tool 444 the grinding wheel 162 is driven at a speed faster than its speed when being engaged by the crusher roller 346, but at a reduced speed as compared to its speed when engaging the pipe to grind threads thereon. It will be remembered that the vertical position of the tool 444 with respect to the grinding wheel 162 is simultaneously adjusted by the handwheel 486 through flexible shaft 408 etc. to compensate for the reduction in grinding wheel diameter under the action of crusher roller 346.

The previous description covers the normal usage and sequence of operation of the crusher roller and diamond tool 444 when merely renewing the serrated grinding wheel 162. It is to be understood however that this sequence may be changed for various purposes. When a new grinding wheel is first placed upon the machine it must first be dressed to a true cylindrical surface by the tool 444 before the crusher roller is applied. Referring to Figure 3 it will be seen that the bracket 434 will have to be shifted upon the dresser base 428 so that the tool 444 will reciprocate horizontally to dress the wheel 162 to a cylindrical surface. After this operation the dresser base 428 is rotated to its proper inclined position and the serrated profile may be imparted to the wheel 162 by the crusher roller 346, following which the grooves may be beveled off by the same diamond tool 444.

This same sequence of operation truing, crushing, then beveling of the tool 444 and crusher roller 346 may be used whenever the surface of the grinding wheel 162 is to be entirely renewed, as because of broken or shipped serrations, or because a thread of a different pitch is to be ground upon the pipe, in which event a different crusher roller 346, of proper pitch, will be required.

When the taper grinding wheel 474 is dressed, the grinding wheel slide 466 is at the right end of its stroke as viewed in Figure 11, and the grinding wheel is rotated slowly at about the same speed as the wheel 162 was rotated while being dressed by the diamond tool 444. The handwheel 534 is now adjusted so that the stop plate 636 on bracket 588 is shifted slightly to the left of the position where it has remained since the last dressing operation. Hydraulic cylinder 628 is now actuated to move the dresser slide 594 to the left where it is stopped by engagement of the plate 634 with the stop plate 636, thus placing the tool 612 in position for its wheel dressing operation. Hydraulic cylinder 618 is now actuated and moves tool 612 slowly across the grinding wheel 474 and then back again. Hydraulic cylinder 628 may now move the dresser slide 594 back to the right

although this is optional, as previously described. The adjustment of handwheel 534 to permit the tool 512 to reduce the diameter of the grinding wheel also moves the bracket 578 carrying the hardened plate 584 towards the right, as previously explained. This permits the grinding wheel to move farther to the left, under the action of hydraulic cylinder 468, before it is stopped by engagement of plate 584 with the stop plate 586, thus automatically compensating for the reduction in diameter of the taper grinding wheel 474.

Electrical circuit and hydraulic system

The manner in which the various parts of the machine are made to operate automatically and in proper timed relationship is shown schematically by the diagrams Figures 18 and 18A which will now be explained.

For the operation of the several hydraulic devices a pump 800 (Figure 18A) is provided. This pump draws hydraulic fluid from a suitable reservoir 802 through line 804 and discharges the fluid under pressure through line 806 whereby it is delivered to a series of solenoid operated control valves namely valves V15, V16, V17, V18, V19, V20, V21 and V22. The solenoids which operate these valves in well-known manner are designated S15A, S15B, S16A, S16B, etc. as shown on the drawing. S17A and S17B, for example, are the coils at opposite ends of valve V17. When solenoid S17A is energized, the valve V17 is thereby set to conduct fluid from line 806 to line 838 and to conduct fluid from line 840 to the exhaust conduit 836. When solenoid S17B is energized, the valve V17 is thereby reversed to conduct fluid under pressure from line 806 to line 840, and to conduct fluid from line 838 to exhaust conduit 836.

The valves V15 and V19 are of a different type in which, using valve V15 as an example, when both solenoids S15A and S15B are energized, line 806 is connected directly to line 812. The energization of solenoid S15A only causes the fluid passing through the valve from line 806 to line 812 to be subjected to volume control so that, if desired, a much smaller volume of fluid enters line 812 than would be the case if both solenoids were energized. If solenoid S15B only is energized, the full volume of the fluid is conducted from line 806 to line 814. Such valves are familiar to those skilled in the art and further detailed description thereof is unnecessary.

The electrical control lines L1 and L2 carry the current for energizing the various relays and solenoids and are connected to any convenient source of electrical energy having the proper current characteristics.

In order to set the several valves properly for the beginning of the cycle, the limit switch LS30 is provided. When no pipe is in the machine, switch LS30 is closed, closing circuit from L2, through a relay coil R1A and switch LS30 to line L1. The relay R1 is of the two-coil, mechanically held type. When the coil R1A is energized by the above circuit, the associated contacts C1A are closed and are mechanically held closed after coil R1A is deenergized. If coil R1B is energized, however, the contacts C1A are opened and contacts C1B are closed, and are likewise mechanically held closed until coil R1A is again energized. All relays employed in the present control circuit are of the same type and the above description is thought to suffice for all.

Therefore, when contacts C1A are closed circuits are closed from L2 through S16A (on valve V16), line 900, and through C1A to L1; through S23A, line 900, C1A to L1; and through S24A, line 900, C1A to L1, energizing solenoids S16A, S23A and S24A. Solenoids S23A and S24A are associated with the valves V23 and V24 whose purpose will later appear.

As shown on the diagram, the hydraulic line 808 from valve V16 is connected to the entrance port of valve V23. With solenoid S23A energized as above described, valve V23 connects line 808 to line 816 which leads to the entrance port of valve V24. With solenoid S24A energized as above described, line 816 is connected to the left hand exit port of valve V24, which is plugged. Pressure also exists at this time in the branch line 818 which leads to the entrance port of the valve V25. Valve V25 is spring operated in one direction and hydraulically operated in the other. It is connected by line 820 through the check valve 822 and flow control valve 824 to line 826.

The discharge line 828 from valve V23 leads to the sequence valve 830, which is also connected to line 826. Valve 830 may be adjusted to any desired pressure, within certain limits, above which pressure fluid will pass from line 828 into line 826 and below which pressure the fluid from line 828 will enter the air pressure accumulator 832. It will be noted from the diagram that line 826 is connected to one end of the valve V25 to shift the piston therein when the fluid pressure in line 826 is great enough to overcome the pressure of the counteracting spring therein. Thus, it should be understood that, when no pressure exists in line 826, valve V25 closes line 818 and when pressure does exist in line 826, valve V25 connects line 818 to line 820.

At the start of the cycle, therefore, the energization of S23A as above described connects the line 828 to the line 834 which leads to the left hand end of cylinder 638. This cylinder 638 is also shown in Figure 15 and has been previously described. The energization of solenoid S16A connects the line 810 leading from the right hand end of cylinder 638 to the exhaust line 836. It is obvious, therefore, that no pressure exists in either side of cylinder 638 since the left hand side is connected to the accumulator 832. It necessarily follows that no pressure exists in line 826 and that therefore line 818 is closed by valve V25.

The valve V17 is connected by the lines 838 and 840 to the dresser operating cylinder 628. The solenoids S17A and S17B which control the operation of this valve are energized through circuits which may be closed by the manually actuated switches SW31 and SW32 respectively. In the normal operating cycle, these switches are allowed to remain open and the solenoids S17A and S17B are deenergized with valve V17 set to deliver fluid under pressure through line 840 to the forward end of cylinder 628 and thus the dresser slide 594 may be maintained in inoperative position.

The valve V18 is connected by the lines 842 and 844 to opposite ends of the transversely operating dresser cylinder 618. The solenoids S18A and S18B which control the operation of valve V18 are energized through circuits which, during the normal operating cycle remain open so that the solenoids S18A and S18B are deenergized with valve V18 set to deliver fluid under pressure through line 842 to the left hand end of cylinder 618. Thus the dresser slide 600 is maintained in inoperative position.

The valve V20 is connected by lines 846 and 848 to opposite ends of the crusher slide operating cylinder 364. The solenoids S20A and S20B

which control the operation of valve V20 are energized by circuits which, during the normal operating cycle remain open so that the solenoids S20A and S20B are deenergized with valve V20 set to deliver fluid under pressure through line 848 to the forward end of cylinder 364. Thus, crusher slide 328 is held in inoperative position.

The valve V21 is connected by lines 850 and 852 to opposite ends of the dresser operating cylinder 445. The solenoids S21A and S21B which control the operation of valve V21 are energized by circuits which, during the normal operating cycle, remain open so that the solenoids S21A and S21B are deenergized with valve V21 set to deliver fluid under pressure through line 850 to the left hand end of cylinder 445. Thus, dresser slide 442 is maintained in inoperative position.

The valve V22 is connected by line 854 to the center port of the cylinder 47. This port is located between the opposed pistons in said cylinder, so that fluid entering cylinder 47 from line 854 will force the pistons toward the opposite ends of the cylinder and thereby close the attached chucks 38 and 40. Valve V22 is connected to both ends of cylinder 47 by line 856 so that fluid entering cylinder 47 from this line will force the opposed pistons toward the center of the cylinder and thereby open the chucks.

A limit switch LS33 (Figure 18) is attached to the machine to be actuated by the thread grinding wheel slide 100 when said slide is in its rearward or inoperative position. Switch LS33 is provided with three sets of contacts, namely LS33—1, LS33—2 and LS33—3. Of these, contacts LS33—1 and LS33—3 are closed when slide 100 has advanced to grinding position while contacts LS33—2 are closed when slide 100 is retracted. Since slide 100 is retracted at the beginning of the cycle, as will be shown in detail later, contacts LS33—2 are closed at that time and a circuit is closed from L2 through relay R2B and contacts LS33—2 to L1, energizing relay R2B. Closing of contacts C2B closes a circuit from L2 through relay R3B, C4B, and C2B to L1. Contacts C4B are associated with relay R4, neither coil of which is energized at the start of the cycle so that C4B is either mechanically held closed from previous operation or must be manually set to complete the above circuit which energizes relay R3B.

Closing of contacts C3B closes a circuit from L2 through solenoid S22B and C3B to L1, energizing solenoid S22B which disposes the piston of valve V22 to permit fluid to pass from the pressure line 806 through line 856 to the ends of cylinder 47. As before explained, this results in chucks 38 and 40 being maintained in open position. At the same time, valve V22 connects line 854 to exhaust line 836 to permit fluid to escape from the central portion of cylinder 47.

As described above, valve V15 is connected by lines 812 and 814 to cylinder 468, while valve V19 is connected by lines 858 and 860 to opposite ends of cylinder 106. Cylinders 468 and 106 operate the taper grinding wheel slide 466 and the thread grinding wheel slide 100, respectively. Since none of the solenoids which operate valves V15 and V19 are energized at the start of the cycle, all lines to cylinders 468 and 106 are closed by said valves and the fluid in said cylinders is trapped and without pressure. Both slides 466 and 100 are previously withdrawn rearwardly as far as possible.

The above mentioned timer mechanism 685, driven by gear 684 of Figure 14, comprises a rotatable disc to which are attached two switch operating dogs 862 and 864 lying in different planes respectively. Dog 862 is rigidly attached and is arranged to operate the limit switch LS34 only. The other three limit switches LS35, LS36 and LS37 may be arranged at a greater distance from the center of the disc and in a different plane than switch LS34 so that the latter three switches will not be operated by dog 862. Dog 864 is necessarily of a latch-type construction so as to operate the limit switches in one direction of rotation only. Such mechanisms are known to those familiar with the art and need not be further described.

Installed for operation by one of the chuck yokes 44 is a limit switch LS38 having two sets of contacts, LS38—1 and LS38—2. As shown in the drawing the contacts LS38—1 are closed when the yokes 44 and 46 have closed the chucks and contacts LS38—2 are closed when the chuck cylinder pistons are forced toward the center of cylinder 47 to open the chucks 38 and 40. At the beginning of the cycle, as explained above, the chucks are open and contacts LS38—2 are therefore closed. A circuit is thereby established from L2 through relay R5B and LS38—2 to L1, energizing R5B.

Therefore, after the manually operated switch SW39 is closed, the closing of contacts C5B closes a circuit from L2 through SW39, the conventional forward-reverse motor starter 866, contacts C6A and C5B to L1. Contacts C6A are associated with relay R6, and since neither of the coils of relay R6 is energized, contacts C6A remain closed from the preceding cycle or must be closed manually. The above described circuit through motor starter 866 provides the control current for setting the starter to operate spindle motor 42 in the reverse direction. The power for this motor is supplied by the lines L3 and L4 from a separate power source. As hereinbefore described, spindle motor 42 also drives the leadscrew 738 and the timer 685. It will be understood that with motor 42 operating in the reverse direction, the disc of timer 685 rotates in the clockwise direction as seen in Figure 18 and during this rotation, dog 864 does not operate the limit switches.

The motor 482 for driving the taper grinding wheel 474 is arranged for two-speed operation by the conventional starter 868 to which power lines L3 and L4 are also connected. A limit switch LS40 for controlling the speed of this motor is installed to be operated by the transverse dresser slide 600. With the dresser slide in retracted position, as above, the contacts LS40—2 are closed and a circuit is closed from L1 through LS40—2 and starter 868 to L2 to operate motor 482 at a relatively high grinding speed. The other control line enters starter 868 from L1 through a start button SW41 and stop button SW42. Start button SW41 must be pressed to complete the circuit and start the motor.

A similar circuit is provided for the thread grinding wheel motor 184 which is driven through a starter 870. The starting line leads to starter 870 through a stop button SW43 and start button SW44. A limit switch LS45 is operated by the crusher slide 328. When the slide 328 is retracted contacts LS45—2 are closed. A second limit switch LS46 is installed for operation by the dresser slide 442. When slide 442 is retracted.

as during the operating cycle, contacts LS46—2 are closed. Contacts LS45—2 and LS46—2 complete the motor control circuit from L2 through starter 870, LS45—2 and LS46—2 to L1. This connection causes motor 184 to operate at the relatively high grinding speed. The power for this motor is also supplied by lines L3 and L4. To begin the actual operation of the machine the pipe to be operated upon is moved axially through the chucks 38 and 40 by a pipe handling table or other similar apparatus. This entering pipe will strike and open the limit switch LS30, opening the circuit L2, R1A, LS30, L1, thereby deenergizing relay R1A. Contacts C1A remain closed, however, until relay coil R1B is energized.

The further advance of the pipe to be threaded causes it to encounter the stop bar 650 (Figure 18A) on the forward end of the rod 644. The previously described coaction between rod 644, pinion 658 and switch actuator rod 664 causes the latter, as rod 644 moves rearwardly under the impact and momentum of the pipe, to move forwardly. This causes one of the dogs of rod 664 to move out of contact with a limit switch LS47 opening the single pair of contacts thereof.

During the rearward motion of rod 644, hydraulic fluid is forced out of the rear end of cylinder 638 through line 834, valve V23, line 828 and valve 830 into the accumulator 832 to increase the resisting pressure therein. When this accumulated pressure reaches the value at which valve 830 has been set to open to line 826, valve 830 opens to permit fluid to pass from line 828 through line 826 to shift the piston of valve V25. As explained above, this opens a hydraulic circuit from pump 800 through line 806, valve V16, lines 808 and 818, valve V25, line 820, check valve 822, flow control valve 824, sequence valve 830, line 828, valve V23 and line 834 to the rearward end of cylinder 638. Thus the flow of fluid from this end of cylinder 638 is reversed and fluid is being introduced into the cylinder under full pump pressure but at low volume as controlled by valve 824. Therefore rod 644 reverses the direction of its motion and moves forward relatively slowly due to the low volume of fluid being used. The pipe to be ground is moved axially ahead of stop bar 650.

This movement continues until the pipe is in the desired position for grinding at which time a second dog attached to rod 664 closes a limit switch LS48. LS48 closes the following circuits: from L2 through relay R7B and switch LS48 to L1; and from L2 through R4A and LS48 to L1. Relays R7B and R4A are therefore energized. Energization of R4A opens contacts C4B interrupting the circuit L2, R3B, C4B, C2B, L1. Also, contacts C4A are closed, closing the circuit L2, R3A, C4A, L1 and energizing relay R3A.

Energization of relay R3A opens contacts C3B and opens the circuit L2, S22B, C3B, L1, deenergizing solenoid S22B. Also, contacts C3A are closed to close the circuit L2, S22A, C3A, L1, energizing solenoid S22A. Thus the valve V22 is reversed and fluid moves through said valve and line 854 into the central port of cylinder 47. As described above, this fluid forces the pistons of cylinder 47 toward the ends of the cylinder and closes the chucks 38 and 40 on the pipe.

The movement of the yoke 44 in the chuck-closing operation, actuates limit switch LS38 to open contacts LS38—2 and close contacts LS38—1. Opening of contacts LS38—2 opens circuit L2, R5B, LS38—2, L1, deenergizing R5B. Closing of contacts LS38—1 closes circuit L2, R1B, LS38—1, L1, energizing relay R1B. Energization of R1B opens contacts C1A and circuits L2, S16A, C1A, L1; L2, S23A, C1A, L1 and L2, S24A, C1A, L1, deenergizing solenoids S16A, S23A and S24A. Also, contacts C1B are closed, closing circuits L2, S23B, C1B, L1 and L2, S24B, C1B, L1. The above described energization of relay R7B has closed contacts C7B so that the circuit L2, S16B, C7B, C1B, L1 is also closed at this time, and solenoids S16B, S23B and S24B are energized to reverse valves V16, V23 and V24.

Reversal of these valves opens line 828 to exhaust and connects line 834 to line 808 and through valve V16 to the exhaust line 836 so that no more fluid moves into cylinder 638 and the movement of rod 644 ceases momentarily. Any fluid remaining under pressure in the accumulator 832 is expended through line 828, valve V23, line 816 and valve V24 into the exhaust line 836. Reversal of valve V16 also permits fluid under pressure to flow from pressure line 806 through line 810 into the forward end of cylinder 638 to force rod 644 in the rearward direction. Naturally, the pipe to be ground, which is now seized in the chucks 38 and 40 remains in position while the bar 650 is withdrawn out of the way of the grinding wheels.

As rod 644 withdraws rearwardly, rod 664 moves forwardly to open limit switch LS48 and close limit switch LS47. Opening of LS48 opens the circuit L2, R7B, LS48, L1, deenergizing R7B. Circuit L2, R4A, LS48, L1 is also opened to deenergize R4A. Closing of LS47 closes the circuit L2, R7A, LS47, L1 and energizes R7A. This energization opens contacts C7B and closes contacts C7A. Opening of contacts C7B opens circuit L2, S16B, C7B, C1B, L1, deenergizing S16B. Valve V16 differs from the other valves in that it is self-centering, that is, when current is cut off from both solenoids, the piston does not remain in its last open position, but assumes a central position which closes all lines leading thereto. Since this is the case at this period of the cycle, lines 808 and 810 are closed and the fluid in both ends of cylinder 630 is trapped and without pressure. Rod 644 therefore stops at this "rest" position which, it will be noted is the same position in which it was set at the beginning of the cycle.

Up to this point in the cycle, the timer 685 has been rotating very slowly in a clockwise direction with the dog 862 passing limit switches LS36 and LS35 without touching them and with dog 864 also passing said switches and touching but not actuating them. Now the dog 862 arrives at the switch LS34 and closes its single pair of contacts. Closing of switch LS34 closes the circuit L2, R6B, LS34, L1, energizing R6B, opening C6A and closing C6B. Closing of contacts C6B closes circuit L2, R5A, C7A, C6B, LS38—1, L1, energizing relay R5A, opening C5B and closing C5A1 and C5A2. The opening of contacts C6A and C5B opens the circuit from L2 through motor starter 866, C6A, C5B, L1. At the same time, closing contacts C5A1 closes the circuit from L2 through motor starter 866, C5A1 to L1. This reverses the direction of the motor field current and drives the motor in the opposite or forward direction. Obviously, the direction of rotation of timer 685 and leadscrew 738 is also reversed. As timer 685 begins to rotate in the counterclockwise direction dog 862 moves off switch LS34, permitting it to open and break the circuit L2, R6B, LS34, L1, deenergizing relay R6B.

The timer 685 continues to rotate in the counterclockwise direction until the dog 864 closes

limit switch LS35. A limit switch LS49 is mounted on the support 458 of the taper grinding mechanism for actuation by a dog on the wheel slide 466. Switch LS49 has two pairs of contacts, namely, LS49—1 and LS49—2. When slide 466 is in its retracted position, as has been the case heretofore in the cycle, switch LS49 is not contacted by its dog and contacts LS49—1 are closed. These contacts, together with limit switch LS35 now close the circuits L2, R6A, LS49—1, LS35, L1 and L2, R8A, LS49—1, LS35, L1 energizing relays R6A and R8A. Contacts C6B therefore open, opening circuit L2, R5A, C7A, C6B, LS38—1, L1, deenergizing R5A.

Closing of contacts C8A closes circuit L2, S15A, C8A1, L1 and circuit L2, S15B, C8A2, L1 energizing solenoids S15A and S15B. As before stated, the simultaneous energization of these solenoids opens valve V15 to allow the full volume of hydraulic fluid from pump 800 and line 806 to pass through line 812 to the rearward end of cylinder 468 to effect the rapid advance of wheel slide 466 to operating position.

The timer dog 864 continues to rotate, opening limit switch LS35 and circuits L2, R6A, LS49—1, LS35, L1 and L2, R8A, LS49—1, LS35, L1 deenergizing relays R6A and R8A. The contacts associated with these relays, however, remain closed. A limit switch LS50 having three pairs of contacts, LS50—1, LS50—2 and LS50—3, is installed to be actuated by the movement of wheel slide 466. As shown in the drawing, contacts LS50—2 are closed when slide 466 is retracted and contacts LS50—1 and LS50—3 are closed when slide 466 begins to advance, while contacts LS50—2 are opened. The further advance of slide 466 also causes limit switch LS49 to be actuated, opening contacts LS49—1 and closing LS49—2.

Closing of contacts LS49—2 closes circuits L2, R8B, LS49—2, L1, energizing relay R8B. Closing of contacts LS50—3 and C8B closes circuit L2, R9A, LS36—1, LS50—3, C8B, L1, energizing relay R9A and closing contacts C9A. The opening of contacts C8A upon the energization of R8B opens the circuit L2, S15B, C8A2, L1 and deenergizes solenoid S15B. Solenoid S15A is energized by a new circuit L2, S15A, C9A, L1 since the old circuit L2, S15A, C8A1, L1 was also cancelled by the energization of relay R8B. Thus, valve V15 is controlled only by solenoid S15A and as before stated this results in the delivery through line 812 to cylinder 468 of a small volume of high pressure fluid which serves to advance slide 466 further but at a very slow rate of speed. It is during this slow advance of slide 466 that the actual work of grinding is done by wheel 474.

When the work of grinding wheel 474 is completed, the continued rotation of timer 685 in the counterclockwise direction causes dog 864 to actuate limit switch LS36, opening contacts LS36—1 and closing contacts LS36—2. Opening of contacts LS36—1 opens circuit L2, R9A, LS36—1, LS50—3, C8B, L1, deenergizing relay R9A. Closing of LS36—2, closes circuits L2, R10A, LS50—1, LS36—2, C5A2, L1; L2, R9B, LS36—2, C5A2, L1 and L2, R11B, LS36—2, C5A2, L1, energizing relays R10A, R9B and R11B. The energization of R9B opens contacts C9A and circuit L2, S15A, C9A, L1 is opened, deenergizing solenoid S15A. Energization of R10A closes contacts C10A which close circuit L2, S15B, C10A, L1, energizing solenoid S15B which now becomes the only solenoid controlling valve V15 and which, as before explained causes valve V15 to reverse. Fluid is therefore conducted from line 806 through valve V15 and line 814 to the forward end of cylinder 468 causing the grinding wheel slide 466 to be rapidly retracted from the work. The rearward end of cylinder 468 is open through line 812 and valve V15 to exhaust line 836.

The withdrawal of taper grinding slide 466 opens contacts LS49—2, LS50—1 and LS50—3 and closes LS49—1 and LS50—2. Opening of LS50—1 opens circuit L2, R10A, LS50—1, LS36—2, C5A2, L1, deenergizing R10A. Opening of LS49—2 opens circuit L2, R8B, LS49—2, L1, deenergizing relay R8B. Closing of contacts LS50—2 closes circuit L2, R10B, LS50—2, L1, energizing relay R10B, opening contacts C10A and closing contacts C10B. The circuits L2, R9B, LS36—2, C5A2, L1 and L2, R11B, LS36—2, C5A2, L1 are opened as the dog 864 moves away from limit switch LS36, opening contacts LS36—2 and closing LS36—1.

A limit switch LS51 is mounted on the cross slide 90 of the thread grinding unit in position to be actuated by a dog on the wheel slide 100. When slide 100 is retracted, as has been the case thus far in the working cycle, switch contacts LS51—1 are closed and contacts LS51—2 are open. Closing of contacts C10B as above closes circuit L2, R12A, LS51—1, C11B, C10B, L1, energizing relay R12A, opening contacts C12B and closing contacts C12A1 and C12A2. Opening of contacts C10A opens circuit L2, S15B, C10A, L1, deenergizing solenoid S15B and causing valve V15 to close both lines to cylinder 468 and stop all motion of the wheel slide 466.

Closing of contacts C12A1 and C12A2 closes circuits L2, S19A, C12A2, L1 and L2, S19B, C12A1, L1, energizing both solenoids S19A and S19B and permitting the full flow of oil from line 806 to pass through valve V19 and line 858 into the rearward end of cylinder 106. As a result, wheel slide 100 advances rapidly to approach the work.

At the start of its forward movement, wheel slide 100 releases limit switch LS33, opening contacts LS33—2 and closing contacts LS33—1 and LS33—3. Opening of contacts LS33—2 opens circuit L2, R2B, L1, deenergizing relay R2B. The rapid advance of slide 100 ends as the slide comes into grinding position when the dog on said slide actuates limit switch LS51, opening contacts LS51—1 and closing contacts LS51—2. Opening of contacts LS51—1 opens circuit L2, R12A, LS51—1, C11B, C10B, L1, deenergizing relay R12A. Closing of contacts LS51—2 closes circuit L2, R12B, LS51—2, L1 energizing relay R12B, opening contacts C12A1 and C12A2 and closing contacts C12B.

Closing of contacts LS33—3 and C12B closes circuit L2, R13A, LS37—1, LS33—3, C12B, L1, energizing relay R13A opening contacts C13B and closing contacts C13A. Opening of contacts C12A1 opens circuit L2, S19B, C12A1, L1, deenergizing solenoid S19B. Opening of contacts C12A2 opens circuit L2, S19A, C12A2, L1 deenergizing solenoid S19A but the latter is immediately reenergized by the closure of C13A which closes the circuit L2, S19A, C13A, L1.

Solenoid S19A alone operates valve V19 so that the flow of fluid to cylinder 106 is regulated and reduced to the amount necessary to provide the proper infeed speed for the grinding operation which is now initiated by grinding wheel 162.

When the thread grinding operation is completed by grinding wheel 162, the continued counterclockwise rotation of timer 685 causes dog 864 to trip limit switch LS37, opening contacts

LS37—1 and closing LS37—2. Opening of contacts LS37—1 opens circuit L2, R13A, LS37—1, LS33—3, C12B, L1, deenergizing relay R13A. Closing of contacts LS37—2 closes circuits L2, R4B, LS37—2, C5A2, L1; L2, R13B, LS37—2, C5A2, L1 and L2, R11A, C13B, LS37—2, C5A2, L1, energizing relays R4B, R13B and R11A. Energization of R11A opens contacts C11B and closes contacts C11A which close circuit L2, R2A, LS33—1, C11A, L1, energizing relay R2A. Energization of relay R4B opens contacts C4A which opens circuit L2, R3A, C4A, L1, deenergizing relay R3A.

Energization of relay R13B opens contacts C13A and closes contacts C13B. Opening of contacts C13A opens circuit L2, S19A, C13A, L1, deenergizing solenoid S19A. Energization of relay R2A opens contacts C2B and closes contacts C2A which close circuit L2, S19B, C2A, L1, energizing solenoid S19B. This solenoid shifts valve V19 to permit fluid to pass from pressure line 806 through line 860 to the forward end of cylinder 106 to cause wheel slide 100 to withdraw rapidly away from the work.

When the slide 100 has been completely withdrawn, contacts LS51—2, LS33—1 and LS33—3 are opened and contacts LS51—1 and LS33—2 are closed. Opening of contacts LS51—2 opens circuit L2, R12B, LS51—2, L1, deenergizing R12B. Opening of contacts LS33—1 opens circuit L2, R2A, LS33—1, C11A, L1, deenergizing relay R2A. In addition, the timer dog 864 has moved beyond limit switch LS37, opening contacts LS37—2 and closing LS37—1. Opening of contacts LS37—2 opens circuits L2, R4B, LS37—2, C5A2, L1; L2, R13B, LS37—2, C5A2, L1 and L2, R11A, C13B, LS37—2, C5A2, L1, deenergizing relays R4B, R13B and R11A.

Closing of contacts LS33—2 closes circuit L2, R2B, LS33—2, L1, energizing relay R2B, opening contacts C2A and closing contacts C2B. Closing of contacts C2B closes circuit L2, R3B, C4B, C2B, L1, energizing relay R3B, opening contacts C3A and closing contacts C3B.

Opening of contacts C2A opens circuit L2, S19B, C2A, L1, deenergizing solenoid S19B and thereby closing both lines 858 and 860 to cylinder 106 and stopping the movement of slide 100. Opening of contacts C3A opens circuit L2, S22A, C3A, L1, deenergizing solenoid S22A. Closing of contacts C3B closes circuit L2, S22B, C3B, L1, energizing solenoid S22B. This reverses valve V22 to permit fluid to pass from line 806 through line 856 into the ends of cylinder 47, meanwhile connecting line 854 to the exhaust line 836. Consequently, the yokes 44 and 46 are rocked toward each other and the chucks 38 and 40 are opened to permit the removal of the finished pipe.

The movement of yoke 44 opens contacts LS38—1 and closes contacts LS38—2. Opening of contacts LS38—1 opens circuit L2, R1B, LS38—1, L1, deenergizing relay R1B. Closing of contacts LS38—2 closes circuit L2, R5B, LS38—2, L1, energizing relay R5B, opening contacts C5A and closing contacts C5B. Opening of contacts C5A1 breaks the forward spindle drive circuit L2, starter 866, C5A1, L1. Closing of contacts C5B closes the reverse drive circuit to the spindle motor: L2, starter 866, C6A, C5B, L1 to drive the spindle, leadscrew and timer in the reverse direction.

Removal of the pipe from the machine allows LS30 to close, closing the circuit L2, R1A, LS30, L1, energizing relay R1A, opening contacts C1B and closing contacts C1A. Opening of contacts C1B opens circuits L2, S23B, C1B, L1 and L2, S24B, C1B, L1, deenergizing S23B and S24B. Closing of contacts C1A closes circuits L2, S16A, C1A, L1; L2, S23A, C1A, L1 and L2, S24A, C1A, L1, energizing solenoids S16A, S23A and S24A. This brings the control circuit to the condition required at the beginning of the cycle and the machine is ready to receive the next work piece.

The operation of dressing the taper grinding wheel 474, when this is found to be necessary, is instituted with the circuit in condition for starting the cycle. The switch SW31 is pressed, closing the circuit L2, S17A, SW31, L1 energizing solenoid S17A. Solenoid S17A then shifts the piston of valve V17 to connect line 840 to exhaust line 836 and to permit fluid under pressure to pass from line 806 through line 838 to the rearward end of dresser cylinder 628. Thus slide 594 is advanced to grinding wheel 474, such advance being stopped at the proper point by the mechanical stop means described above and shown in Figure 11. The switch SW31 may be released immediately, opening the circuit L2, S17A, SW31, L1 and deenergizing solenoid S17A. Valve V17 however does not shift until solenoid S17B is energized.

The switch SW52 is then pressed to close the circuit L2, S18B, SW52, L1, energizing solenoid S18B. Solenoid S18B shifts the piston of valve V18 to connect line 842 to exhaust line 836 and to permit fluid under pressure to pass from line 806 through line 844 to the right hand end of dresser cylinder 618. Thus the travel of transverse slide 600 toward the left is begun. It will be noted that a flow control valve 874 is installed between line 806 and lines 842 and 844 so that the quantity of fluid reaching cylinder 618 and hence the speed of slide 600 may be effectively controlled.

Switch SW52 may be released immediately, opening the circuit L2, S18B, SW52, L1 and deenergizing solenoid S18B. Valve V18, however, remains in the same position as before. The slide 600, as it begins to move toward the left, releases the limit switch LS40, opening contacts LS40—2 and closing contacts LS40—1. The opening of contacts LS40—2 opens the high speed motor control circuit L2, 868, LS40—2, L1. The closing of contacts LS40—1 closes the low speed motor control circuit L2, 868, LS40—1, L1, causing motor 482 to be driven at a low speed suitable for dressing the grinding wheel 474.

Slide 600 proceeds to the left, passing the diamond tool 612 across the surface of wheel 474 and renewing said surface to the desired contour. When the desired extent of transverse motion of slide 600 has been reached, said slide closes the limit switch LS53, closing the circuit L2, S18A, LS53, L1 and energizing solenoid S18A. Thus the piston of valve V18 is shifted to open line 844 to exhaust line 836 and to permit fluid from line 806 to pass through line 842 to the left hand end of cylinder 618 whereby slide 600 is moved toward the right.

Immediately, limit switch LS53 is again opened, opening the circuit L2, S18A, LS53, L1 and deenergizing solenoid S18A. Valve V18, however, remains undisturbed. When slide 600 has completed the return travel across the surface of wheel 474, it again actuates limit switch LS40, opening contacts LS40—1 and closing contacts LS40—2. The opening of contacts LS40—1 opens the low speed motor control circuit L2, 868, LS40—1, L1. The closing of contacts LS40—2

closes the high speed motor control circuit L2, 868, LS40—2, L1 and the speed of motor 474 is thereby again increased to the proper grinding speed.

Switch SW32 is then pressed, closing the circuit L2, S17B, SW32, L1 to energize solenoid S17B and shift the piston of valve V17. Line 838 is thereby connected to exhaust line 836 and fluid is permitted to pass from line 806 through line 840 to the forward end of cylinder 628 to withdraw slide 594 out of operative position. Thus the dressing operation is completed, leaving the circuit in the same condition as when it was initiated.

The operation of dressing the thread grinding wheel 162, either to provide a cylindrical surface or to bevel the "throat" as previously described, is begun by closing the switch SW54 to close the circuit L2, S21A, SW54, L1, energizing the solenoid S21A. Solenoid S21A shifts the piston of valve V21 to connect line 850 to exhaust line 836 and to permit fluid to pass from line 806 through line 852 into the right hand end of dresser cylinder 445. Switch SW54 may be released, opening circuit L2, S21A, SW54, L1 and deenergizing solenoid S21A.

Accordingly, slide 442 is moved toward the left, the speed of such movement being controlled by the flow control valve 876 installed between line 806 and valve V21. At the start of its movement, slide 442 releases limit switch LS46, opening contacts LS46—2 and closing contacts LS46—1. The opening of contacts LS46—2 opens the high speed motor control circuit L2, 870, LS45—2, LS46—2, L1. The closing of contacts LS46—1 closes the low speed motor control circuit L2, 870, LS46—1, L1 as a result of which the speed of motor 184 and grinding wheel 162 is reduced to the proper dressing speed.

The slide 442 proceeds toward the left, passing the diamond tool 444 across the grinding wheel 162 to perform the required dressing operation. When the desired limit of leftward travel is reached by slide 442, said slide closes the limit switch LS55, closing the circuit L2, S21B, LS55, L1, energizing solenoid S21B and shifting the piston of valve V21 to connect line 852 to exhaust line 836 and to permit fluid to pass from line 806 through line 850 into the left hand end of cylinder 445. Thus slide 442 is returned to its original position.

At the beginning of the return movement of slide 442, limit switch LS55 is again openend, opening the circuit L2, S21B, LS55, L1 and deenergizing solenoid S21B. At the end of the return movement, slide 442 again actuates limit switch LS46, opening contacts LS46—1 and closing contacts LS46—2. The opening of contacts LS46—1 opens the low speed motor control circuit L2, 870, LS46—1, L1. The closing of contacts LS46—2, closes the high speed motor control circuit L2, 870, LS45—2, LS46—2, L1 and the speed of motor 184 is again increased to the proper grinding speed. This concludes this dressing operation, leaving the control circuit again in position to begin a work cycle, or to permit operation of the crusher wheel mechanism as the case may be.

To operate the crush dressing mechanism for renewing the thread or other contour on grinding wheel 162, the switch SW56 is closed, closing the circuit L2, S20B, SW56, L1 and energizing solenoid S20B. Solenoid S20B shifts the piston of valve V20 to connect line 848 to exhaust line 836 and to permit fluid to pass from line 806 through line 846 into the rearward end of crusher cylinder 364. Switch SW56 may be released, opening the circuit L2, S20B, SW56, L1 to deenergize solenoid S20B.

Crusher slide 328 is thus started forward into operating position. At the begining of such movement, slide 328 releases limit switch LS45, opening contacts LS45—2 and closing contacts LS45—1. The opening of contacts LS45—2 opens the high speed motor control circuit L2, 870, LS45—2, LS46—2, L1. The closing of contacts LS45—1 closes the extra low speed motor control circuit L2, 870, LS45—1, L1, whereby the speed of the grinding wheel motor 184 is reduced to the very low speed required for the crush-dressing operation. Closing of contacts LS45—1 also closes a control circuit through the motor starter 880 which drives the crusher roller 346. This circuit conducts current from line L2 through starter 880 and LS45—1 to L1, to start the motor 354 and roller 346. Additionally, motors 354 and 184 are synchronized, by any of the well known methods, when both are operating to prevent relative motion between the peripheral surfaces of grinding wheel 162 and roller 346. Roller 346 then continues to press into the surface of grinding wheel 162 and to produce or renew the desired contour thereon, until stopped by the engagement of blocks 368 and 372 of Figure 4. It will be noted that the speed of the advance of slide 328 and roller 346 is regulated by the flow control valve 878 installed in line 846.

At the end of the crush dressing operation, slide 328 closes limit switch LS57, closing the circuit L2, S20A, LS57, L1, energizing solenoid S20A. This solenoid causes valve V20 to reverse position, connecting line 846 to exhaust line 836 and permitting fluid to pass from line 806 through line 848 into the forward end of cylinder 364 which causes slide 328 to be withdrawn from the grinding wheel 162.

At the start of this withdrawing movement, slide 328 opens limit switch LS57, opening the circuit L2, S20A, LS57, L1, deenergizing solenoid S20A but not altering the position of valve V20. When it is fully retracted, slide 328 again actuates limit switch LS45, opening contacts LS45—1 and closing contacts LS45—2. The opening of contacts LS45—1 opens the circuit L2, 880, LS45—1, L1, stopping motor 354. Also opened is the extra low speed motor control circuit L2, 870, LS45—1, L1. Closing of contacts LS45—2 closes the high speed motor control circuit L2, 870, LS45—2, LS46—2, L1 to increase the speed of motor 184 to the proper grinding speed. This completes this dressing operation and again the circuit is left in condition to permit beveling of the wheel by the diamond tool 444 as previously described.

Summary of automatic operation

At the start of a cycle of operation, both the taper grinding slide 466 and thread grinding slide 100 are retracted rearwardly as far as possible. This position of slide 100 closes limit switch contacts LS33—2, closing electrical circuits which energize solenoid S22B. Solenoid S22B operates valve V22 to cause cylinder 47 to hold the chucks 38 and 40 open.

The limit switch LS30, intended to be opened by a pipe entering the chucks, is closed at this time. Circuits are therefore closed which energize the solenoids S16A, S23A and S24A. These solenoids operate the respective associated valves

in the hydraulic system to remove pressure from both ends of cylinder 638. The locating bar 644 is therefore maintained in work-receiving position.

The start button SW39 is pressed to start spindle motor 42 in the reverse direction. The start buttons SW41 and SW44 are pressed to start taper wheel motor 482 and thread wheel motor 184 respectively. The machine is then ready for the introduction of a length of pipe into the chucks 38 and 40.

As the pipe is brought into the machine, it opens limit switch LS30 and continues to strike stop bar 650, moving rod 644 rearwardly. This movement of rod 644, as explained above, causes a dog on the rod 664 to open limit switch LS47. Rod 644, being connected directly to the piston of cylinder 638, forces fluid out of cylinder 638 into the accumulator 832. The increase of pressure in accumulator 832 initiates a hydraulic circuit which results in the reversal of flow to cylinder 638 so that rod 644 is moved towards the chucks to urge the pipe into proper grinding position.

When this position has been reached, a dog on rod 664 closes limit switch LS48. As a result of the electrical circuits thereby established, solenoid S22B is deenergized and solenoid S22A is energized. This reverses the position of valve V22 causing cylinder 47 to close the chucks 38 and 40 on the pipe.

The movement of yoke 44 during the closing of the chucks actuates limit switch LS38 which establishes electrical circuits resulting in the deenergization of solenoids S16A, S23A and S24A, and the energization of solenoids S16B, S23B and S24B, reversing valves V16, V23 and V24. The consequent hydraulic circuit reverses the flow to cylinder 638 so that the rod 644 is withdrawn from the end of the pipe.

The rearward movement of rod 664 opens the limit switch LS48 and closes limit switch LS47. This results in the deenergization of solenoid S16B, whereby valve V16 is permitted to assume its central position, closing the lines to cylinder 638 and stopping rod 644 at its original position.

While the pipe is thus being located and gripped, the motor 42 has been rotating chucks 38 and 40 and timer 685. The timer dog 864, rotating in a clockwise direction now closes limit switch LS34. Electrical circuits are thereby established to reverse motor 42 and drive it in the forward direction.

The direction of rotation of timer 685 is also reversed, as is that of leadscrew 738. Leadscrew 738 now rotates in the proper direction to perform a grinding operation and timer 685 rotates in a counterclockwise direction. This rotation of timer 685 opens limit switch LS34 and later closes limit switch LS35. Switch LS35 establishes electrical circuits which result in the energization of solenoids S15A and S15B. Solenoids S15A and S15B operate valve V15 to cause cylinder 468 to advance taper wheel slide 466 rapidly toward the work.

At the start of its movement wheel slide 466 actuates limit switch LS50 to open contacts LS50—2 and close contacts LS50—1 and LS50—3. Further advance of slide 466 actuates LS49 which establishes electrical circuits to deenergize solenoids S15A and S15B and to reenergize solenoid S15A. Solenoid S15A operates valve V15 to cause cylinder 468 to advance slide 466 at a slow infeed grinding rate of speed. Grinding wheel 474 is thus fed into the work and the taper grinding operation is accomplished.

When this operation is completed, the timer dog 864 actuates limit switch LS36 to establish electrical circuits which deenergize solenoid S15A and energize S15B. This operates valve V15 to cause cylinder 468 to withdraw slide 466 rapidly. The return of slide 466 opens limit switch contacts LS50—1 and LS50—3, closes LS50—2. This establishes electrical circuits which deenergize solenoid S15B and energize solenoids 19A and 19B. Deenergization of solenoid S15B, by operation of valve V15, causes cylinder 468 to stop the movement of slide 466.

Solenoids 19A and 19B operate valve V19 to cause cylinder 106 to effect the rapid advance of thread grinding wheel slide 100 toward the work. At the start of its advance, slide 100 actuates limit switch LS33. When slide 100 reaches grinding position, it also actuates limit switch LS51 which establishes electrical circuits to deenergize solenoids S19A and S19B and to reenergize solenoid S19A only. Solenoid S19A operates valve V19 to cause cylinder 106 to advance grinding wheel slide 100 at a slow infeed grinding rate of speed. Thus thread grinding wheel 162 is fed into the work and threads are ground upon the pipe as the leadscrew moves the grinding wheel 162 axially of the work.

At the end of the thread grinding operation, timer dog 864 operates limit switch LS37 to establish electrical circuits resulting in the deenergization of solenoid S19A and the energization of solenoid S19B. Solenoid S19B operates valve V19 to cause cylinder 106 to withdraw slide 100 away from the work.

The movement of slide 100 actuates limit switch LS33 while timer dog 864 has now passed beyond limit switch LS37, releasing it. This establishes electrical circuits which cause the deenergization of solenoids S19B, S22A and the energization of S22B. Deenergization of solenoid S19B causes valve V19 to close all lines to cylinder 106, stopping slide 100 at its original inoperative position.

The solenoid S22B reverses valve V22 to cause cylinder 47 to open chucks 38 and 40 so that the finished pipe may be withdrawn. The movement of yoke 44 in the opening of the chucks actuates limit switch LS38 which again reverses the direction of rotation of spindle motor 42, driving spindle, timer and leadscrew in reverse.

The finished pipe is then removed, closing limit switch LS30 which results in the deenergization of solenoids S23B and S24B and the energization of solenoids S16A, S23A and S24A. Thus the circuit is restored to its original condition.

We have described an automatic system of operating the machine wherein the thread grinding wheel 162 is not advanced toward the work piece to grind the threads until after the taper grinding wheel 474 has completed its work and been withdrawn. While this is the normal manner of operating the machine it is to be understood that if desired, both grinding wheels may engage the work at the same time. In order to accomplish this, the work is rotated in a direction such that a point on its periphery is ground first by the taper grinding wheel 474 before that point rotates to the position where it is ground by the thread grinding wheel 162.

The invention may be embodied in other specific forms without departing from the spirit or essential characteristics thereof. The present embodiment is therefore to be considered in all respects as illustrative and not restrictive, the scope of the invention being indicated by the

appended claims rather than by the foregoing description, and all changes which come within the meaning and range of equivalency of the claims are therefore intended to be embraced therein.

What is claimed and desired to be secured by United States Letters Patent is:

1. In a grinding machine, means for holding a work piece; a first grinding wheel and means for moving said wheel into engagement with a portion of the work piece; a second grinding wheel and means for moving said second wheel into engagement with the same portion of the work piece, whereby a plurality of grinding operations may be performed upon the same portion of the work piece; limit means controlling the movement of said wheels towards the work piece in accordance with the intended finished dimension of the work piece; means for dressing one of said grinding wheels, said last mentioned means controlling said limit means to compensate for the change in diameter of said one grinding wheel from a dressing operation.

2. In a grinding machine, means for holding a work piece; a first grinding wheel and means for moving said wheel into engagement with a portion of the work piece; a second grinding wheel and means for moving said second wheel into engagement with the same portion of the work piece, whereby a plurality of grinding operations may be performed upon the same portion of the work piece; limit means controlling the movement of said wheels towards the work piece in accordance with the intended finished dimension of the work piece; means for dressing said grinding wheels, said last mentioned means controlling said limit means to compensate for the change in diameters of said grinding wheels by the dressing operations.

3. In a grinding machine, means for holding a work piece; a first grinding wheel and means for moving said wheel into engagement with a portion of the work piece; a second grinding wheel and means for moving said second wheel into engagement with the same portion of the work piece, whereby a plurality of grinding operations may be performed upon the same portion of the work piece; limit means controlling the movements of said wheels towards the work piece in accordance with the intended finished dimension of the work piece; independent means for dressing each of said grinding wheels, said independent means each controlling said limit means to compensate for the change in diameters of said grinding wheels from a dressing operation.

4. In a forming machine, a chuck for holding and rotating a work piece; a grinding wheel; said wheel and chuck being relatively movable to grind a work piece; stop means engageable by a work piece during insertion thereof into said chuck, said stop means being operable to locate the work piece and to control the closing of said chuck; and means operable to control the timing of the relative movement of said grinding wheel and chuck.

5. In the device described in claim 4, said last named means being operated in timed relationship with the rotation of said chuck.

6. In a forming machine, a chuck for holding and rotating a work piece; means for rotating said chuck; a serrated, thread grinding wheel; said wheel and chuck being relatively movable to grind a work piece; stop means engageable by a work piece during insertion thereof into said chuck, said stop means being operable to locate the work piece and to control the closing of said chuck; leadscrew means for shifting said grinding wheel axially; and a timer driven by said chuck rotating means and operable to control the timing of the relative movement of said grinding wheel and chuck, and said leadscrew means.

7. In a forming machine, means for holding a work piece; a pair of grinding wheels movable to engage the work piece; a timer operable to control the sequence of movement of said grinding wheels, and mechanical stops to limit the movement of said wheels towards said work.

8. In the device of claim 7, means for rotating said work piece; and a connection between said last mentioned means and said timer whereby said timer is driven thereby.

9. In the device of claim 8, a leadscrew operable to shift one of said grinding wheels substantially axially, said leadscrew being driven by said work rotating means.

10. In the device of claim 7, said timer controlling the length of grinding operation of the first of said grinding wheels and the termination of the grinding operation of the second of said grinding wheels, said first grinding wheel being operable to control the start of the grinding operation of said second wheel.

11. In a forming machine, a chuck for holding and rotating a work piece; rotating means for said chuck; a grinding wheel movable towards said chuck to grind the work piece; means for moving said wheel rapidly towards said chuck and then slowly while it engages the work piece; a stop limiting the movement of said wheel towards said chuck; means engageable by said wheel moving means during the rapid movement thereof to cause it to move it slowly; and a timer driven by said chuck rotating means, operable to control the movement of said wheel towards and away from said chuck.

12. In the device of claim 11, means for opening and closing said chuck, said means being effective to close said chuck in response to the insertion of a work piece, and said timer being effective to control the opening of said chuck.

13. In the device of claim 11, means for adjusting the position of said stop in accordance with the diameter of the work piece.

14. In a forming machine, a chuck for holding and rotating a work piece; rotating means for said chuck; means for closing said chuck in response to the insertion of a work piece therein; a first grinding wheel; means for moving said wheel towards said chuck to grind the work piece and then away therefrom; an adjustable stop limiting the movement of said wheel towards the chuck in accordance with the work diameter; a timer driven by said chuck rotating means and operable to control the movement of said wheel; a second grinding wheel having a serrated grinding surface to grind threads upon the work piece; means for moving said serrated wheel towards and away from said chuck in response to the movements of said timer and said first grinding wheel; a leadscrew connected to said chuck rotating means to move said serrated wheel substantially axially; and means responsive to the withdrawal of said serrated wheel from the work piece to control the opening of said chuck.

15. The device described in claim 14 wherein means responsive to the removal of the work piece reconditions the machine for the reception of another work piece and automatic cycle of operation.

16. The device described in claim 14 wherein the said means to move the grinding wheels towards the work are effective to move them rapidly during the first portion of their movements and then slowly during the grinding operations.

17. In the device described in claim 14, means for dressing said first grinding wheel, means for moving said dressing means across the face of said grinding wheel, said last mentioned means being operative at the beginning of its movement to reduce the speed of said first grinding wheel, and at the completion of its movement to increase said first grinding wheel to normal grinding speed.

18. In the device described in claim 14, means for dressing said serrated grinding wheel, means for moving said dressing means across the face of said grinding wheel, said last mentioned means being operative at the beginning of its movement to reduce the speed of said serrated grinding wheel, and at the completion of its movement to increase the speed of said serrated grinding wheel to normal grinding speed.

19. In the device described in claim 14; a serrated crusher wheel for renewing the profile of said serrated grinding wheel, crusher wheel rotating means; means for moving said crusher wheel towards and away from said serrated grinding wheel; and means responsive to the movement of said crusher wheel towards said serrated grinding wheel to reduce the speed of the latter and synchronize the grinder and crusher wheel peripheral speeds, and operative in response to the return movement of said crusher wheel to stop its rotation and return the serrated grinding wheel to normal grinding speed.

20. In a thread grinding machine, means for rotating a work piece; a first grinding wheel and means for moving said wheel into engagement with the work piece; a serrated grinding wheel and means for moving said serrated wheel into engagement with the same axial portion of the work piece, said serrated wheel being mounted for rotation about a non-intersecting axis spaced from the work piece axis but making an acute angle therewith; and means including a lead screw for shifting said serrated wheel substantially axially of the work piece at a constant rate of speed while it is engaged with said work piece.

21. In a forming machine, a first base member; a work rotating means mounted upon said first base member; a second base member pivotally mounted upon said first base member on one side of said work rotating means; a cross slide mounted upon said second base member for sliding movement substantially parallel to the axis of said work rotating means; a wheel slide mounted upon said cross slide for sliding movement toward the axis of said work rotating means; a serrated thread grinding wheel mounted upon said wheel slide for rotation about an

axis non-intersecting with and making an acute angle with the axis of said work rotating means; means for moving said wheel slide toward and away from the axis of said work rotating means; and means for sliding said cross slide in timed relationship with the rotation of said work rotating means.

22. In the machine recited in claim 21, a third base member pivotally mounted upon said first base member on the other side of said work rotating means; a second wheel slide mounted upon said third base member for sliding movement toward and away from the axis of said work rotating means; and a grinding wheel mounted upon said second wheel slide for rotation about an axis substantially perpendicular to the direction of sliding movement of said second wheel slide.

23. In a grinding machine, means for rotating a work piece; a first grinding wheel and means for moving said wheel into engagement with the work piece to grind a taper thereon; a serrated grinding wheel and means for moving said serrated wheel transversely into engagement with the tapered portion of the work piece and additional means including a lead screw for shifting said serrated wheel substantially axially of the revolving work piece in timed relation to the speed of rotation thereof during engagement of said serrated wheel with said work piece to grind a thread thereon; and limit means controlling the movement of each of said wheels toward the work piece in accordance with the diameter of the work piece.

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