Sept. 14, 1937. C. C. STEVENS 2,092,895

GRINDING MACHINE

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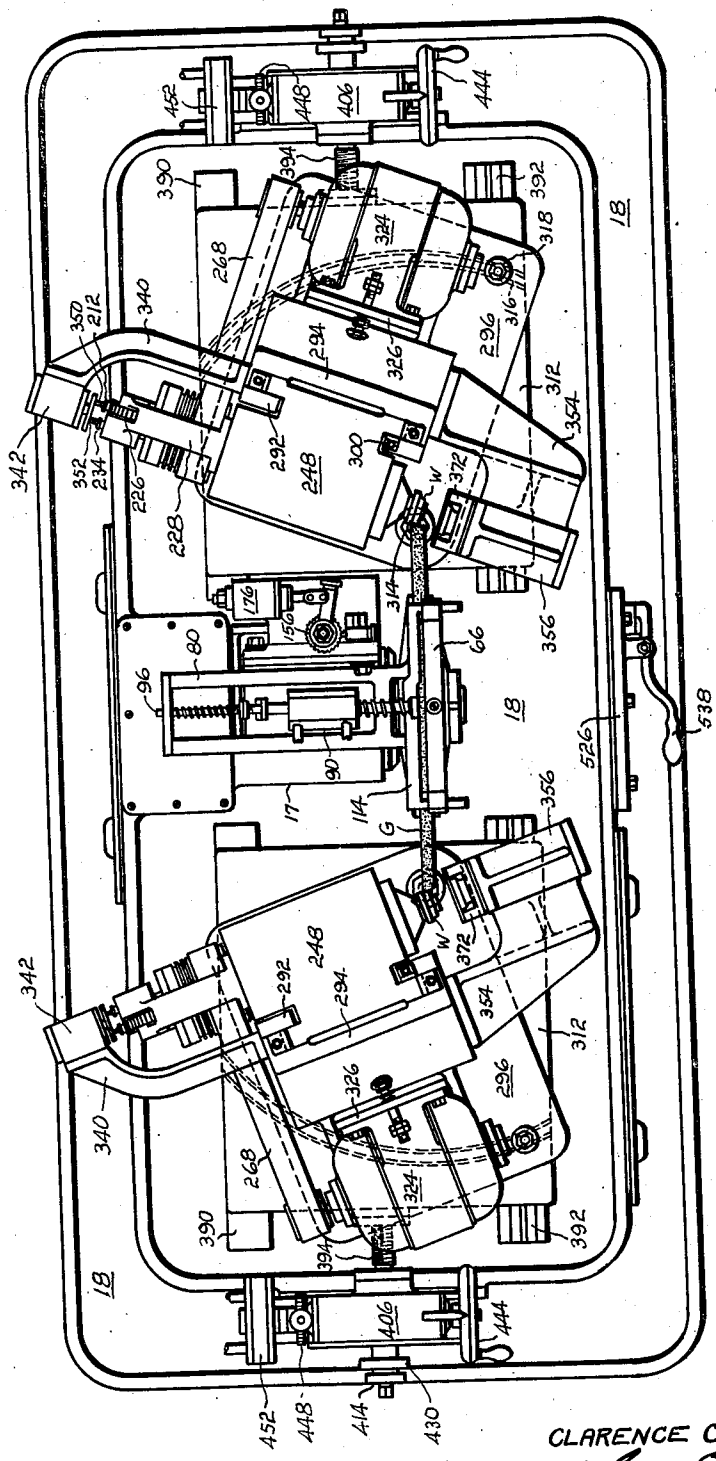


FIG. 1

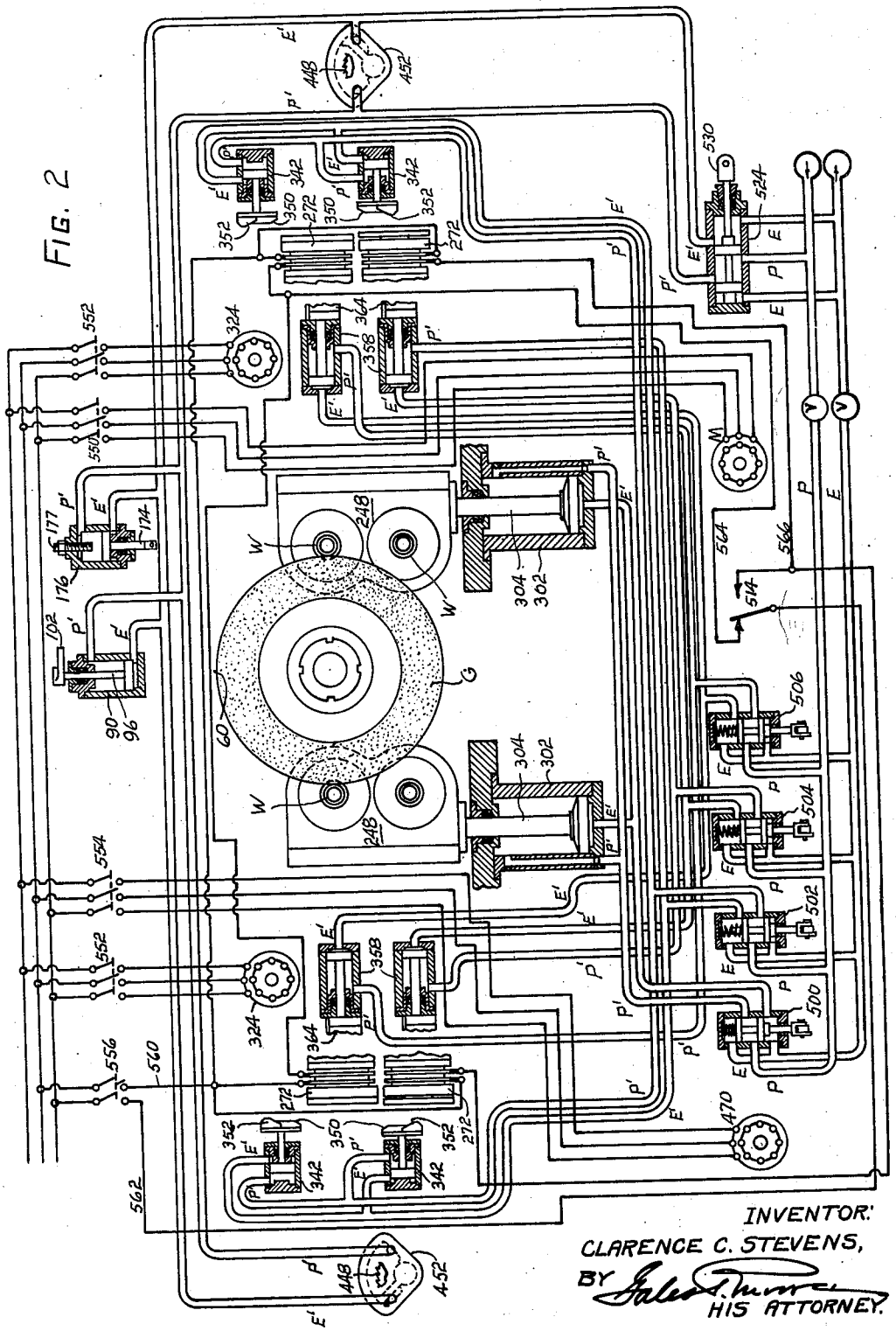
INVENTOR:
CLARENCE C. STEVENS,
BY Fales & Thurston
HIS ATTORNEY.

Sept. 14, 1937. C. C. STEVENS 2,092,895

GRINDING MACHINE

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FIG. 2



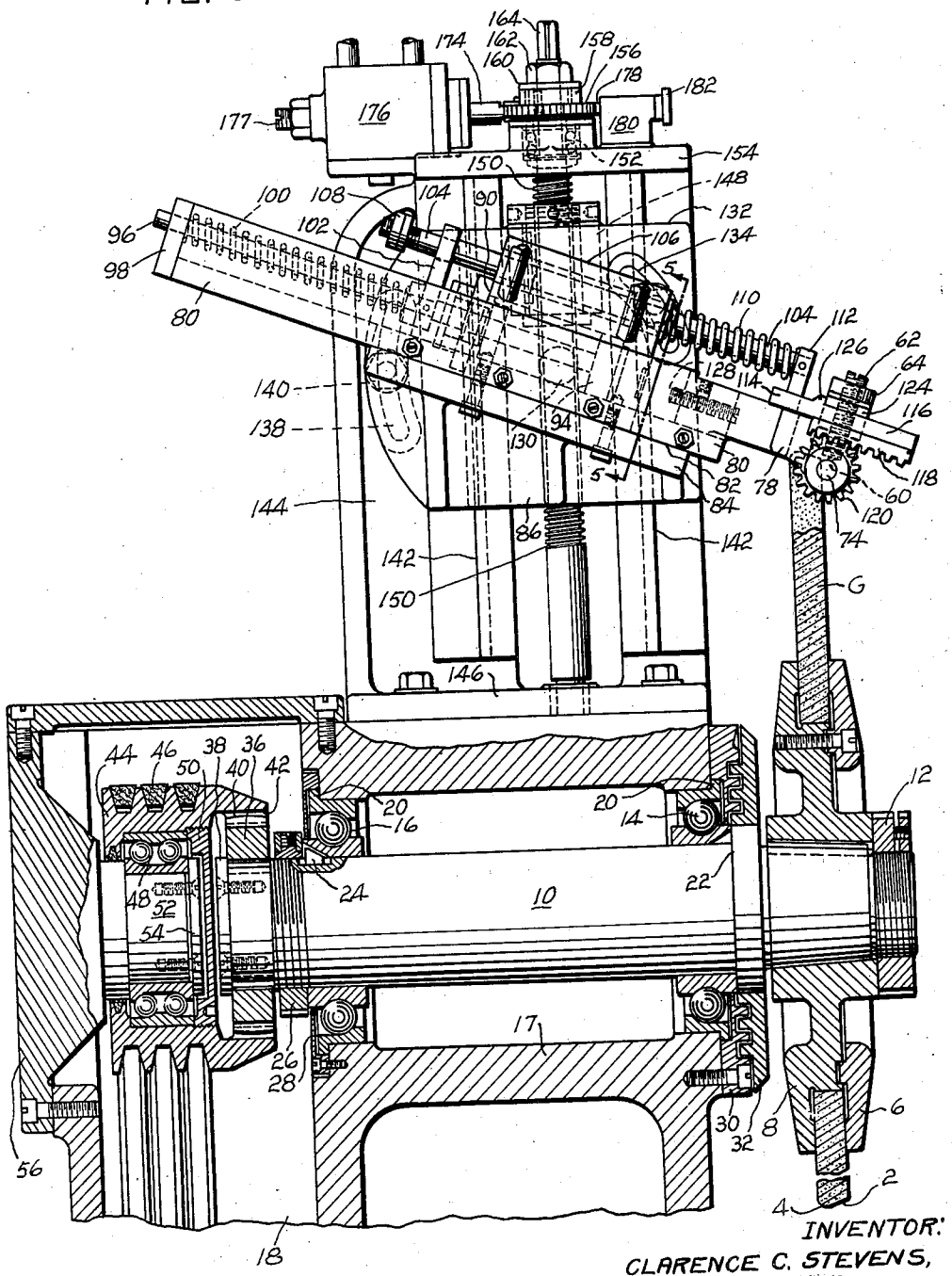
INVENTOR:
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Sept. 14, 1937. C. C. STEVENS 2,092,895

GRINDING MACHINE

Filed July 3, 1934 9 Sheets-Sheet 3

FIG. 3



INVENTOR:
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Sept. 14, 1937. C. C. STEVENS 2,092,895

GRINDING MACHINE

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FIG. 4

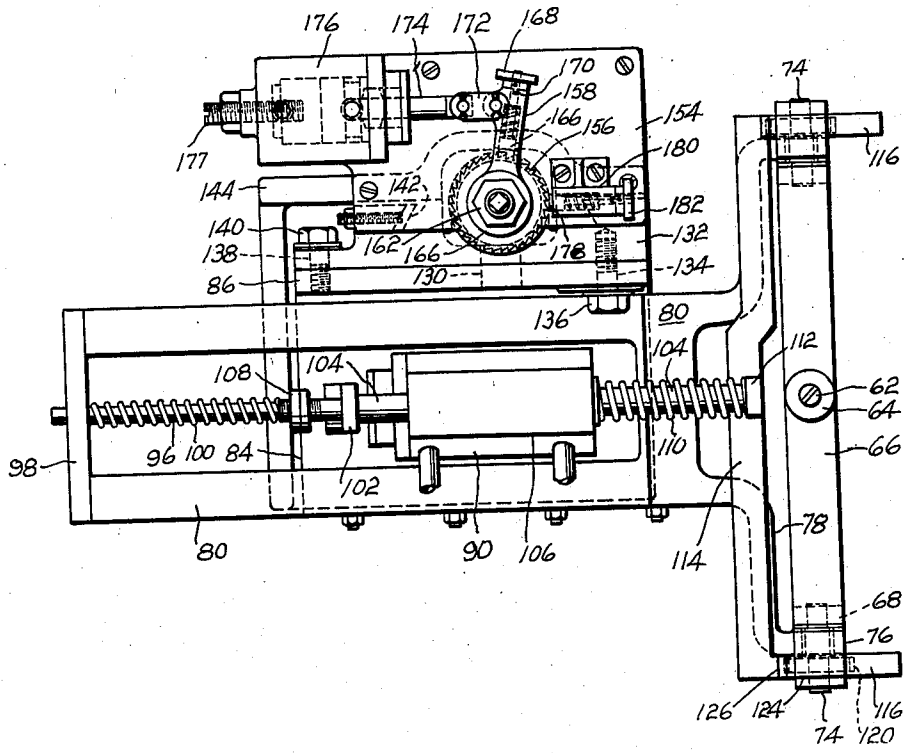


FIG. 5

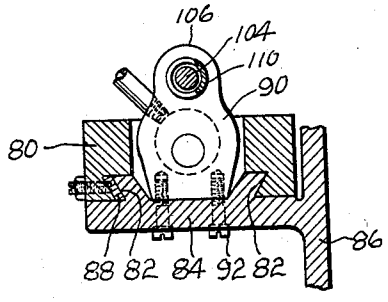
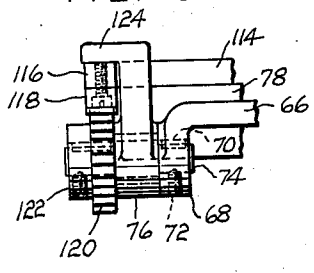


FIG. 6



INVENTOR:
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GRINDING MACHINE

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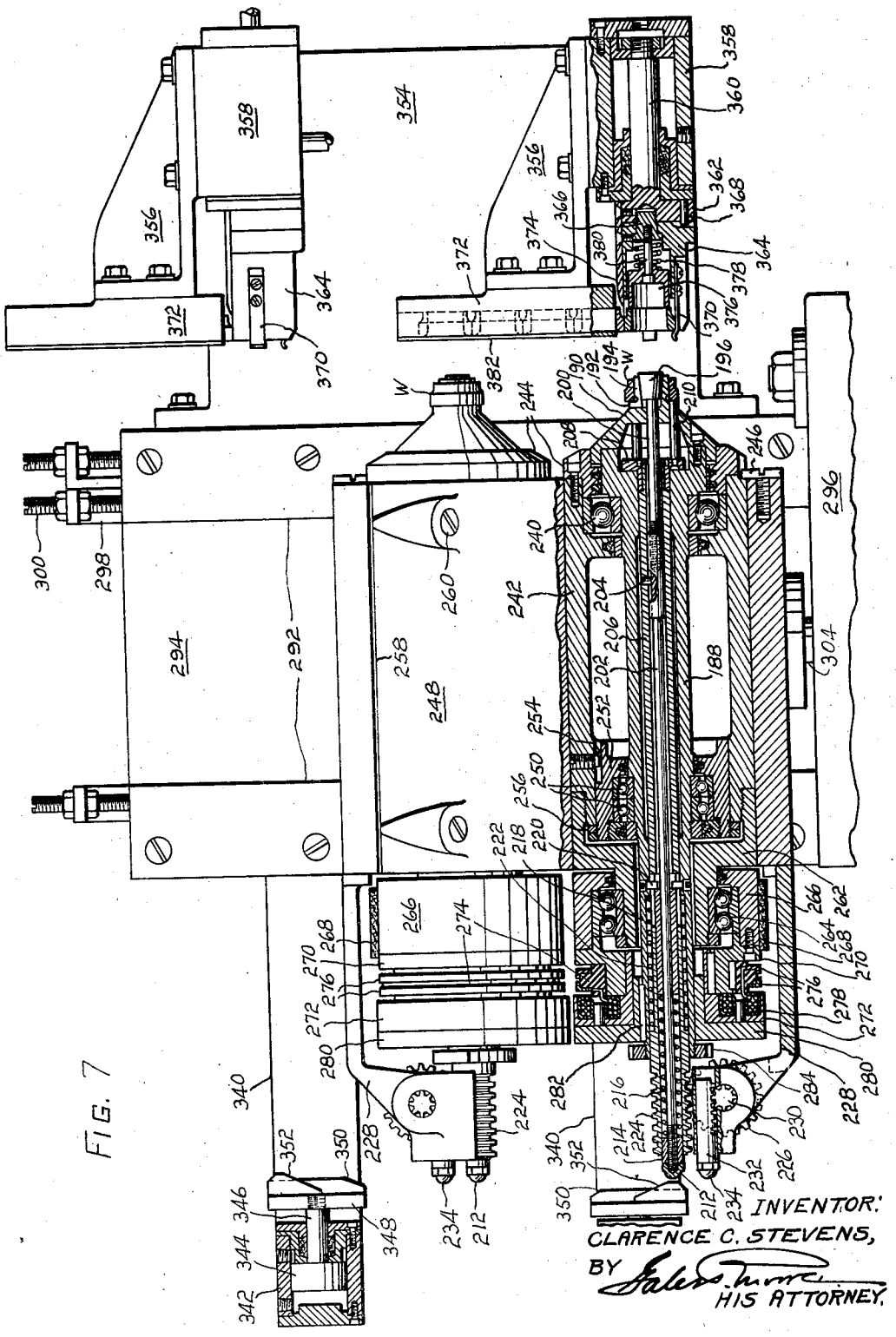


FIG. 7

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GRINDING MACHINE

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FIG. 8

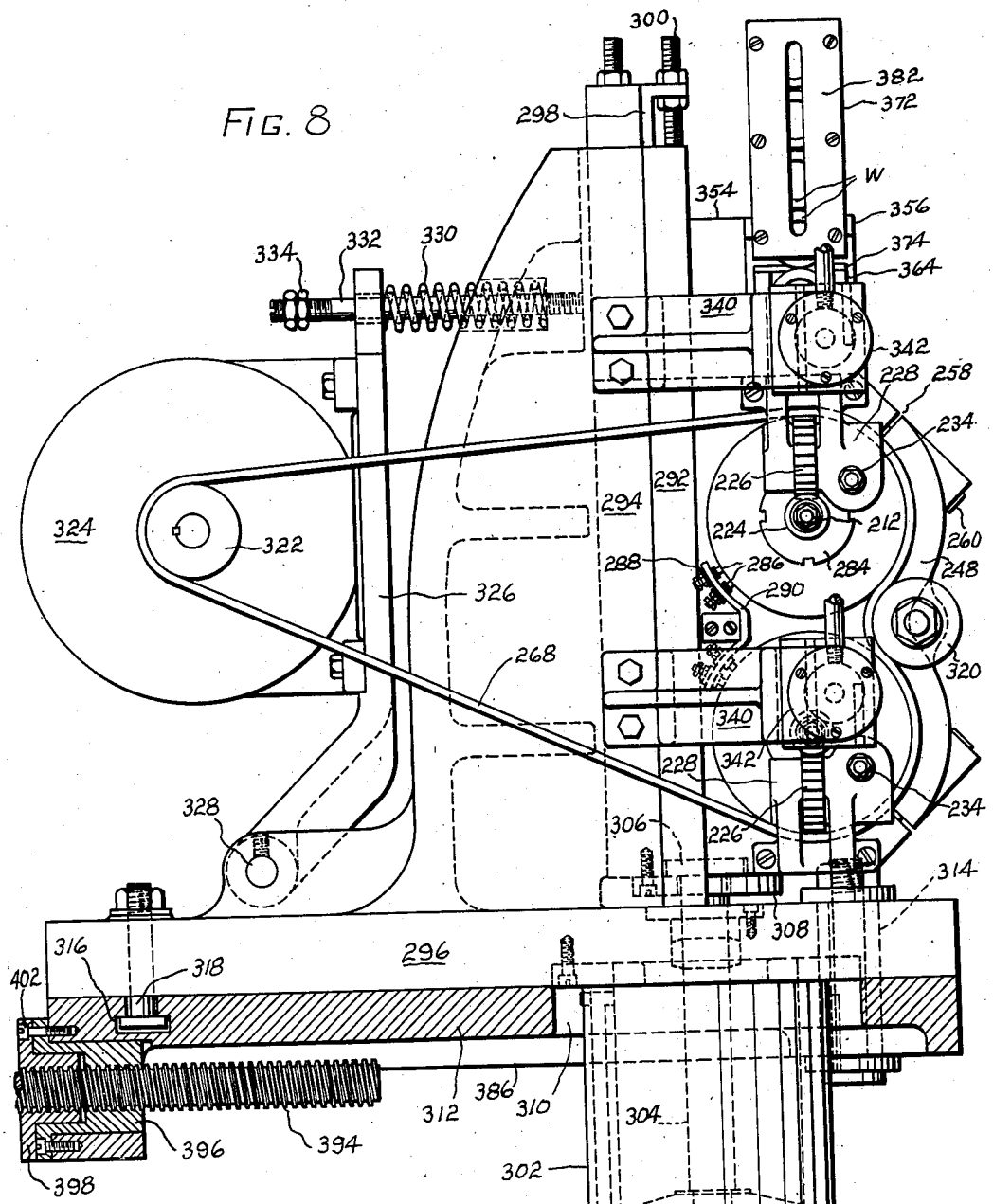
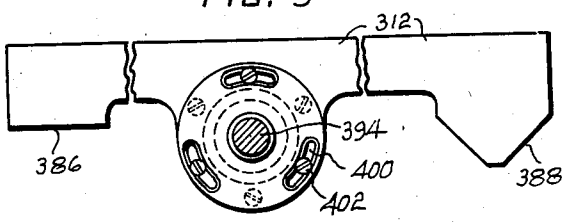


FIG. 9



INVENTOR:
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FIG. 10

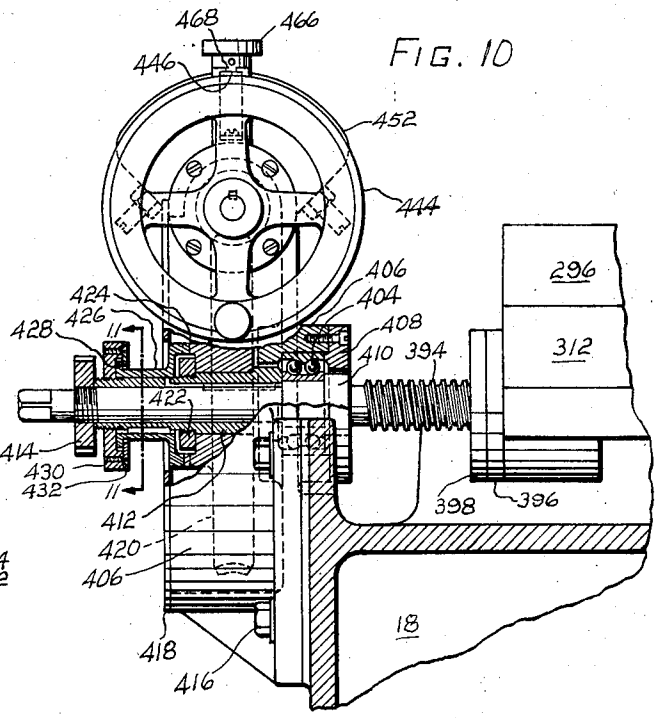


FIG. 11

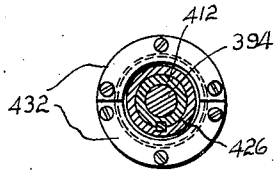


FIG. 12

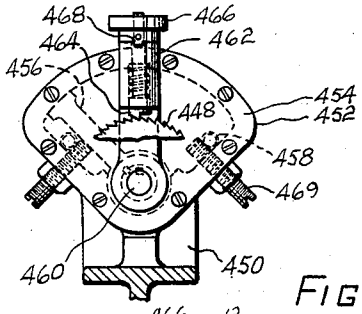
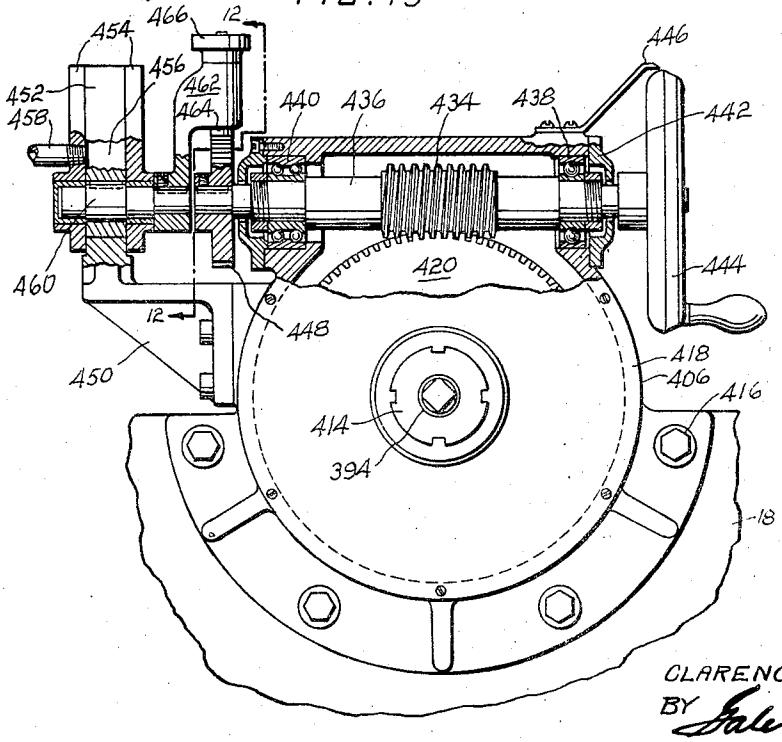


FIG. 13



INVENTOR:
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GRINDING MACHINE

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FIG. 14

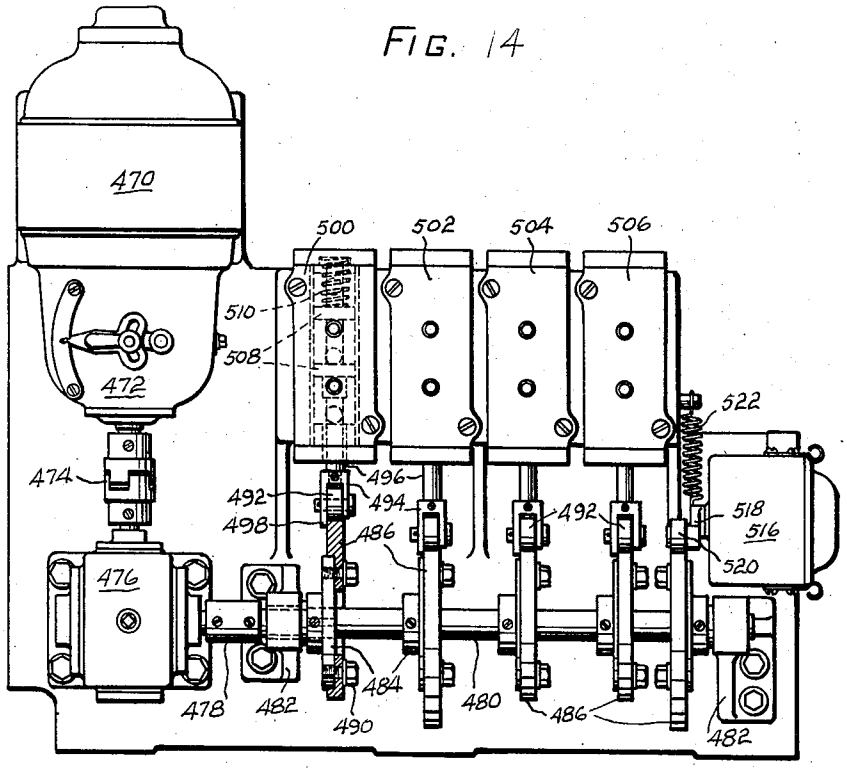
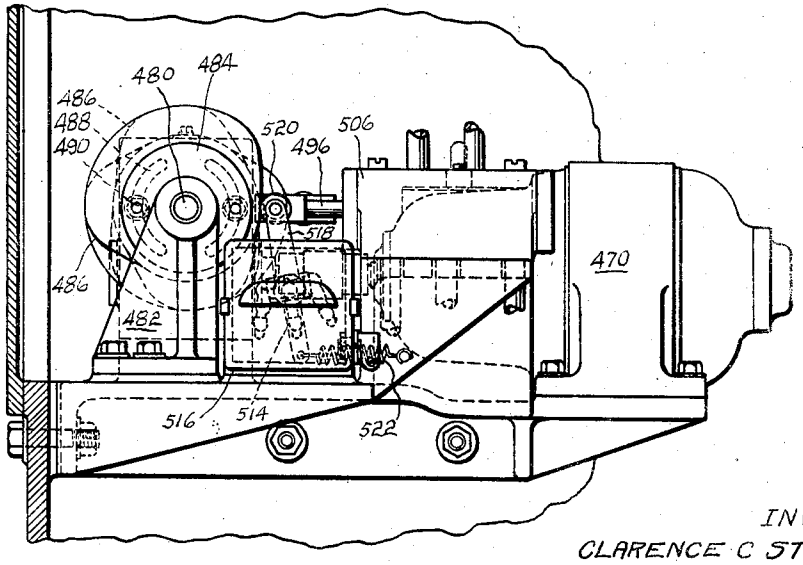


FIG. 15



INVENTOR:
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Sept. 14, 1937. C. C. STEVENS 2,092,895

GRINDING MACHINE

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FIG. 16

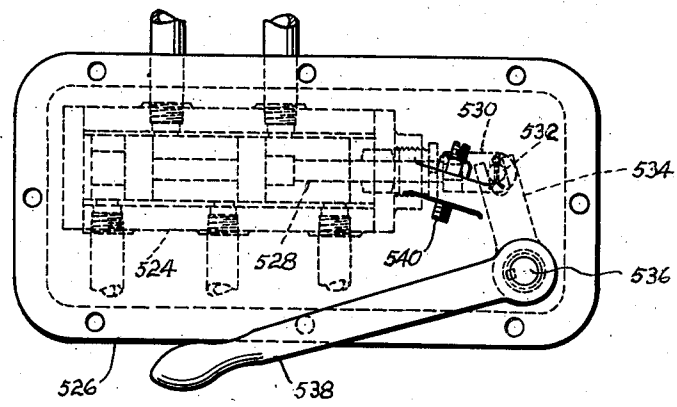
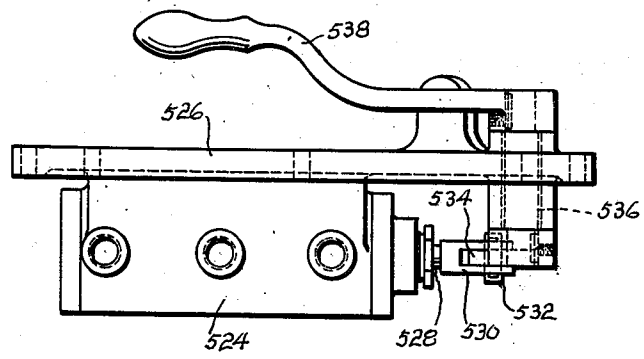


FIG. 17



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Patented Sept. 14, 1937 2,092,895

UNITED STATES PATENT OFFICE

2,092,895

GRINDING MACHINE

Clarence C. Stevens, Forestville, Conn., assignor to General Motors Corporation, Detroit, Mich., a corporation of Delaware

Application July 3, 1934, Serial No. 733,627

19 Claims. (Cl. 51—105)

This invention relates to grinding machines and comprises all of the features of novelty herein disclosed. An object of the invention is to provide an improved form-wheel grinding machine for grinding circular work of transversely contoured form. Another object is to provide a grinding machine having improved means for relatively feeding the work and the grinding wheel, as by having the two engage substantially tangentially and thus accurately determine the work size without the use of a gauge. Another object is to provide a reliable and efficient grinding machine of the multi-spindle type in order to eliminate or reduce the idle time of the machine and get high production. Another object is to provide improved work loading or chucking mechanism. Still another object is to provide improved dressing mechanism for maintaining the form or contour of the grinding wheel. Yet another object is to provide improved spindle driving mechanism.

To these ends and also to improve generally upon machines of this character, the invention consists in the various matters hereinafter described and claimed. In its broader aspects, the invention is not necessarily limited to the specific construction selected for illustrative purposes in the accompanying drawings in which

Figure 1 is a plan view of the machine.

Figure 2 is a diagram of the electrical connections and the fluid pressure system.

Figure 3 is a vertical sectional view of the grinding wheel head, its dressing mechanism being shown in side elevation.

Figure 4 is a plan view of the dressing mechanism.

Figure 5 is a sectional view on the line 5—5 of Figure 3.

Figure 6 is a front view of a portion of the dressing mechanism.

Figure 7 is a side elevation of one of the twin work heads, one work spindle and its associated loader being shown in vertical section and a cam actuating device associated with the other work spindle also being shown in vertical section.

Figure 8 is a rear end view of one of the twin work heads, a portion of its slide and feed mechanism being in section.

Figure 9 is a side view of one of the main slides with its feed screw in section.

Figure 10 is a front view, partly in vertical section, of the feed mechanism for one of the main slides.

Figure 11 is a sectional view along the line 11—11 of Figure 10.

Figure 12 is a front view, with parts broken away, of a portion of the feed mechanism.

Figure 13 is a side view of Figure 10, with parts broken away and in vertical section.

Figure 14 is a plan view of the timing unit, one of the cams being in section.

Figure 15 is a side view of Figure 14.

Figure 16 is a front view of a hand controlled valve, and

Figure 17 is a bottom view of Figure 16.

First outlining briefly the principal functions of the machine and referring to the more important units, the machine has a formed or contoured grinding wheel driven at high speed on a horizontal axis. There are four work spindles which are adapted to be loaded and unloaded and to be reciprocated in a vertical plane to bring the work tangentially into engagement with the grinding wheel. The machine is substantially symmetrical about a vertical axis with a twin or duplex work head carrying two work spindles at each side of the wheel. When either twin work head is lowered to bring the upper work-piece into engagement with the wheel, the lower or finished work piece is released and ejected from the machine and a new work piece is loaded. Then as the twin work head rises to bring the lower and new work piece tangentially into engagement with the grinding wheel, the upper work-piece is released from its spindle and ejected while a new piece is loaded on. Inasmuch as the grinding wheel is subject to wear, it is shaped or trued at intervals by a dressing tool or diamond mounted in the vertical plane through the axis of the grinding wheel. Such dressing tool is mounted for vertical feed adjustment on a vertical radius of the wheel and for a compound dressing movement across the wheel, such compound movement comprising a rectilinear movement to produce a straight or conical surface on the grinding wheel and also a swinging movement to produce an arcuate surface merging with the straight surface. Such a contour is useful, for instance, in grinding the raceway and adjacent surface of a ball bearing race ring. Inasmuch as wear and dressing of the grinding wheel reduces its diameter, means is also provided for giving each twin work head a movement radially of the grinding wheel to compensate. This movement is horizontal and perpendicular to the downward feed adjustment of the dressing tool. Many of the mechanisms are operated by fluid pressure controlled

by valves which are in turn controlled by a timing unit having a cam shaft.

Grinding wheel and mounting

Referring more particularly to Figure 3, G is a grinding wheel whose periphery is shaped to grind such articles as inner ball bearing race rings. Preferably, it has a straight or conical surface 2 merging with or tangent to an arcuate surface 4 as indicated at the bottom of Figure 3. The abrasive material is clamped to a hub 8 by a plate 6, the hub being keyed to a tapered end portion of a spindle 10 and clamped by a nut 12. The spindle is mounted for rotation in ball bearings 14 and 16 having their outer race rings inserted in an opening of a housing 17 carried by a main frame 18. The outer race rings are provided with locating flanges 20 which engage the ends of the housing while the inner race ring of the bearing 14 abuts against a collar 22 on the spindle. The other inner race ring is secured against rotation on the shaft by a key 24 and is adjustable axially of the shaft by a ring nut 26, this last adjustment being to apply an initial load to the bearings and thus prevent play in the spindle. The bearing 16 is covered by a cap plate 28 fastened to the housing by screws and the bearing 14 is protected by a sealing plate 30 attached to the housing and having a plurality of annular, side ribs interfitting with similar annular, side ribs on an outer sealing plate 32 which is pressed on the spindle collar 22.

A driving collar 36 is keyed on the rear end of the spindle 10 and clamped by a plate 38. The driving collar has a plurality of teeth or splines 40 which fit freely between similar teeth 42 projecting inwardly from a pulley 44 which is driven by V-type belts 46 taking their power from an electric motor M (shown only in the diagram). The pulley 44 is journalled for rotation on a double row ball bearing 48 which has its outer race ring clamped in the pulley by a threaded plate 50. The inner race ring of the bearing is clamped by a plate 54 on a stud 52 carried by a bracket 56 fastened to the main frame 18. The purpose of mounting the drive pulley and the spindle on separate bearings is to preclude the possibility of belt pull and whip from being transmitted to the spindle and thus causing vibration or chatter.

Dressing mechanism

A dressing diamond 60 (Fig. 3) is fastened to the lower end of a screw 62 which is secured by a clamping nut 64 in the middle of a substantially horizontal bar 66 (Figs. 4 and 6) arranged above the grinding wheel and having depending lugs 68, each connected by a key 70 and a set screw 72 to a rock shaft 74 which is journalled in bearing lugs 76 on an arm 78 projecting from a slide 80. The slide is mounted for reciprocation on ways 82 (Fig. 5) of a shelf 84 which projects laterally from a vertical plate 86, a gib 88 providing for adjustment of the slide. The slide is slotted to straddle a cylinder 90 which is fastened to the shelf 84 by screws 92. In the cylinder is a piston 94 (Fig. 3) connected to a long piston rod 96 which extends rearwardly and is guided in a guide plate 98 closing the slot in the slide 80. A coiled spring 100 is interposed between the guide plate 98 and an upright arm 102 which is pinned to the piston rod. The upper end of the arm 102 has an opening permitting it to slide with respect to a rod 104 which is guided endwise in an upward extension 106 of the cylinder body, one end of the rod having adjusting nuts 108 to limit relative movement of the arm 102 with respect to the rod. At the front of the rod 104, a coil spring 110 is interposed between the cylinder body extension 106 and an upright lug 112 to which the rod 104 is pinned. The lug 112 is carried by a yoke 114 having arms 116 provided on their under sides with rack bars 118, each rack bar meshing with a pinion 120 whose hub 122 is keyed and fastened to one of the rock shafts 74. A finger 124 projecting upwardly and laterally from the arm 78 overlies the arm 116 and so holds the rack bar in engagement with the pinion. Each arm 116 is provided with a little stop lug 126 which is urged against the finger 124 by the coil spring 110. Thus, it is apparent that, when fluid pressure is admitted to the front of the piston, the piston rod will be shifted rearwardly and, through the coil spring 100, will yieldingly urge the slide 80 rearwardly and always tend to keep the fingers 124 on the arms 78 against the little lugs 126 on the arms 116. When the arm 102 on the piston rod engages the nuts 108, the rod 104 is positively moved rearwardly compressing the spring 110. All the parts connected to the rod 104 and to the slide 80, including the rack bars and pinions, move rearwardly as a unit until a stop screw 128 on the slide 80 engages and is stopped by the cylinder body 90. During this time, the dressing tool is moved along the straight portion 2 of the grinding wheel. The slide and the pinions move no farther but the continued movement of the piston rod and the rod 104 causes the rack bars to move rearwardly with respect to the arrested slide and the pinions, thereby turning the pinions 120 and rocking the diamond-carrying bar 66 around the axis provided by the rock shafts 74. This imparts to the dressing diamond 60 a rocking movement which produces the arcuate surface 4 tangent to and merging smoothly with the straight surface 2 on the grinding wheel. When the pressure fluid is reversed, the spring 100 keeps the stop screw 128 against its abutment temporarily while the diamond is rocked in the other direction by the power stored in the spring 110 and, when the lug 126 again reaches the finger 124, the diamond and its slide are given a rectilinear movement back to starting position.

The plate 86 supporting the dressing mechanism has angular adjustment on a horizontal axis so that the direction of sliding of the diamond can be placed at any desired angle with respect to the grinding spindle, and the whole dressing mechanism can also be fed up and down to compensate for the wearing down of the grinding wheel. To accomplish this, the vertical plate 86 is pivotally connected by a horizontal swivel pin 130 to a vertical feed slide 132 and, to provide for clamping after angular adjustment, the plate 86 is provided with an arcuate slot 134 through which projects a clamping bolt 136. Also the feed slide 132 has an arcuate slot 138 through which projects a clamping bolt 140. The vertical feed slide 132 slides vertically on ways 142 on an upright bracket 144 having a base 146 fastened on top of the housing 17. Fastened to the feed slide 132 is a nut 148 engaging a vertical feed screw 150 which is journalled at its lower end in the base 146 and is journalled at its upper end in a double row ball bearing 152 carried by a top plate 154 of the bracket 144. Keyed to the feed screw shaft is a ratchet wheel 156 and above this is loosely journalled a dog-carrying arm 158 retained by a washer 160 and a nut

162, the latter threaded over the squared end 164 of the feed shaft. In the arm 158 (Fig. 4) is mounted a spring-pressed pawl or dog 166 which engages the ratchet teeth. In order to be able to retract the dog from the ratchet teeth, a knob 168 is pinned to the upper end of the shank of the dog and has a little projection 170 which can be lifted out of a slot in the arm 158 to lock the dog in inoperative position. The arm 158 is pivotally connected by a link 172 with the end of a piston rod 174 projecting from a cylinder 176. An adjusting stop screw 177 in the path of the piston controls the number of ratchet teeth moved by the dog. In order to prevent retrograde movement of the ratchet wheel, a detent dog 178 is mounted in a housing of a bracket 180 and is provided with a knob 182 similar to the knob 168 so that the detent can be retracted and locked away from the ratchet wheel. From the foregoing, it is apparent that, by reciprocation of the piston rod, a step by step feeding movement can be imparted to the ratchet wheel and thus feed the dressing mechanism slowly downwardly. If a rapid vertical adjustment is desired, the dog 166 and the dog 178 can be retracted from the ratchet wheel and locked by pulling on the knobs 168 and 182 and turning them. Then a crank on the squared end 164 of the feed shaft provides for rapid turning of the feed screw.

Work head

Referring more especially to Figure 7, each of the twin work heads has two rotary work spindles 188, each spindle having a nose piece 190 with an abutment shoulder 192 against which a work piece W is clamped. The work is clamped internally in any suitable way, as by yieldable sections 194 forced outwardly or radially by a conical part 196 on a pull-rod 200 which is moved to the left to clamp the work and to the right to release it. The pull-rod is in two sections, its outer section 200 being threaded in an enlargement of an inner section 202. The pull-rod is held from rotation with respect to an ejector sleeve 206 which guides it by a pin 204 projecting from the sleeve into a slot of the enlargement. The ejector sleeve is slidably mounted in and guided by the work spindle, being provided with a head 208 which carries a series of ejector pins 210 for projection through the spindle nose to a position where they will engage the work piece to eject it from the work head.

On the rear end of the push-rod section 202 is a button 212 adapted to be actuated in one direction when moved along a cam, as hereinafter described, to release the work piece. The button is threaded on the end of the rod 202 against a threaded abutment sleeve 214, a coil spring 216 being interposed between the abutment sleeve 214 and a second abutment sleeve 218 which is held from endwise movement by pins 220 which project inwardly from the work spindle, such pins projecting through slots in the ejector sleeve 206 and so compelling the latter to rotate with the spindle. The coil spring 216 urges the pullrod to work-clamping position. Another coil spring 222 is interposed between a shoulder on the ejector sleeve and a shoulder in the spindle for the purpose of urging the ejector to inoperative position. The rear end of the ejector sleeve is formed as a circular rack 224 meshing with a gear 226 on a shaft journalled in a bracket 228 fastened to the work head. A pinion 230 is connected to the shaft carrying the gear 226 and meshes with a rack plunger 232 having a button 234 adapted to be moved along a cam as will hereinafter appear. Both the ejector sleeve and the pull-rod are urged to the left in Fig. 7 by the coil springs and are positively actuated in the work-releasing direction by cams.

Each work spindle is rotatably mounted near the front on a ball bearing 240 whose outer race ring is clamped in a quill 242 by a closure plate 244 fastened to the end of the quill by screws. To prevent turning of the quill, a screw 246 is fastened to the work head 248 with the head of the screw arranged to engage a notch in the periphery of the closure plate 244. The work spindle is also mounted in a pair of abutted ball bearings 250 which have their inner race rings clamped on the spindle by a nut while the outer race rings are clamped by a nut in a sliding housing 252 which is held from rotation with respect to the quill by the end of a screw 254 passed through the quill and entering a slot in the housing. On the end of the sliding housing are adjusting nuts 256 adapted to engage the end of the quill thus to shift the sliding housing endwise and apply preload to the bearings. The housing or head 248 is split longitudinally at two places as indicated at 258 so that each of the quills may be clamped in the housing by means of tangential clamping screws 260 which draw the split sections of the housing together around the quill.

The rear end of the quill 242 is closed by a threaded cap 262 having a reduced extension on which is mounted a double row ball bearing 264 which rotatably supports a pulley 266 driven by a belt 268. The pulley has a cap 270 which is keyed to a magnetic clutch body 272. An insulating collar 274 is keyed to the cap 270 and provided with collector rings 276, each electrically connected to coils 278 housed in the clutch body 272. A clutch plate 280 is slidably connected to the spindle by a key or spline 282 and is limited in its movement in one direction by a ring nut 284 threaded on the spindle. As shown best in Figure 8, the collector rings 276 are engaged by brushes 286 carried by insulating bushings 288 mounted in openings of a bracket 290 fastened on the work head.

Work head slide mechanism

The work head is vertically grooved as appears in Figure 1 and slides with respect to plates 292 which are fastened on an upright standard 294 having a base plate 296. Play in the slide can be taken up by gibs 298 (Figs. 7 and 8) adjusted endwise by screws 300. A cylinder 302 is fastened to the bottom face of the base plate 296 and provided with a piston rod 304 having a head 306 secured to the work head 248 by a collar 308 fastened to the work head by screws. The cylinder projects through an opening 310 in a main slide 312, the opening being large enough to provide for a limited amount of swivel movement of the base plate 296 around a pivot sleeve 314 carried by a main slide 312. The main slide has an arcuate slot 316 (Figs. 1 and 8) which receives a T-headed clamping bolt 318 fastened to the base plate. Thus the base plate can be clamped in any desired angular position on the main slide, such angular adjustment corresponding to the angular arrangement of the dresser mechanism with respect to the axis of the grinding wheel. This angular arrangement of the dresser mechanism and of the work heads is due to the exigencies of location of the formed surfaces 2 and 4 on the grinding wheel. The pivotal axis

of the base plate 296 is in the plane of the wheel and in line with the center of curvature of the surface 4 on the wheel.

Each driving belt 268 is held closely wrapped around the pulleys 266 by an idler roller 320 which is journalled on the workhead, the belt passing around a pulley 322 on the shaft of an electric motor 324 which is secured to a bracket 326 pivotally mounted at 328 on the base plate 296. Inasmuch as the work heads move up and down, it is desirable to take up slack in the belt and this is accomplished by a coil spring 330 interposed between the bracket 326 and an abutment surface on the standard 294. The pivotal movement of the bracket 326 is limited by nuts 334 threaded on a bolt 332 fastened to the standard 294. Brackets 340 are fixed in a horizontal position on the standard 294 and each supports a cylinder 342 having a piston 344 connected to a piston rod 346 carrying a cam plate 348 on which a chucking cam 350 and an ejecting cam 352 are attached. Thus, when the work head rises, the button 212 on the pull rod of the upper work spindle engages the cam 350 and is thus pushed in a direction to unclamp the work. Also, as the adjacent button 234 controlling the ejecting mechanism engages the other cam 352, the work is ejected. The cam 350 has a long straight portion on which the button 212 remains while the button 234 passes beyond or above the cam 352 thus permitting the ejector sleeve to be retracted by its coil spring before a new work piece is clamped. The cams 350 and 352 are afterwards retracted by the piston and cylinder unit in order that, upon the subsequent downward movement of the workhead, the ejector will not operate a second time and so eject the newly acquired workpiece. It will be understood that the downward movement of the work head causes the lower pull-rod and the lower ejector to be operated by the lower set of cams. In describing the approach between work and grinding wheel as substantially "tangential", the applicant has reference to that type of tangential movement by which a particle moving along a straight line in the plane of a circle and tangent to it, approaches more and more slowly to the periphery of the circle until, at the single point of tangency, there is no further approach. The work to be ground represents the particle and the circumference of the grinding wheel represents the circle.

Work loading mechanism

A vertical bracket 354 is fixed to the standard 294 and carries two angled brackets 356 each supporting a loading cylinder 358 having a piston rod 360 with a head 362. A loader 364 is secured to the head by a threaded plug 366 and is held from turning with respect to the head by a pin 368. Three leaf springs 370 are secured to the loader in positions 90° apart in order that a workpiece may be dropped into engagement with the springs from a magazine 372. A retainer plate 374 is secured to the top of the loader and holds the supply of work-pieces in the magazine when the loader with the new work-piece is advanced towards the work spindle. A cup-shaped plunger 376 is urged toward the work spindle by a coil spring 378, a headed bolt 380 limiting the movement. The side of the magazine is closed by a slotted cover 382 which permits a view of the supply of work. When the loader advances, the new work-piece is carried over the spindle nose and pressed against the abutment shoulder 192 thereon by the spring pressed plunger 376 which then yields. The ends of the leaf springs 370 are spread open a little by engagement with the spindle nose and then, as the loader is retracted, the leaf springs slip over the work-piece while the latter is still urged against the spindle nose by the spring-pressed plunger 376. Thereafter, the spring-pressed plunger is retracted by the head of the bolt 380 and, when the retainer plate 374 passes out from under the magazine, another work piece drops down between the leaf springs.

Feed of main slide

As shown in Figures 8 and 9, each main slide 312 is provided with a flat surface 386 and a V-shaped surface 388 for sliding movement on flat ways 390 and V-shaped ways 392 on the main frame. A feed screw 394 is connected to each feed slide by a nut 396. An auxiliary nut 398 projects partly into the main nut 396 and is adjustably secured by screws 402 passing through arcuate slots 400 in a flange of the auxiliary nut. By angular adjustment of the auxiliary nut, all backlash is taken up at the threads. Referring more particularly to Figures 10 to 13, the feed screw 394 is journalled for rotation without endwise movement in a double row ball bearing 404 whose outer race ring is clamped in a housing 406 by a cap 408. The inner race ring of the bearing is secured against a collar 410 on the feed screw by a long sleeve 412 which is keyed to the feed screw and clamped by a nut 414. The housing 406 is fastened to the main frame 18 by screws 416 and the housing is closed by a cover 418. In the housing, a worm wheel 420 is loosely journalled on the sleeve 412 but held from axial movement by a nut 422 threaded on the long sleeve 412. The hub of the worm wheel is provided with clutch teeth at 424 gripping with similar teeth on a sliding clutch member 426 which is keyed to the sleeve 412. The clutch member has a flange 428 loosely mounted in a recess of a threaded collar 430 on the sleeve 412. Arcuate plates 432 (Figs. 10 and 11) are fastened to the threaded collar 430 and overlie the flange 428 so that, upon a manual turning of the threaded collar, the clutch member can be moved endwise to disengage the clutch teeth at 424. This is to provide for a quick turning of the feed screw 394 by a crank attached to the squared end thereof.

The worm wheel 420 is driven by a worm 434 on a shaft 436 which is journalled at one end in a ball bearing 438 and at the other end in a double row ball bearing 440. The bearing 438 is covered by a cap 442 and the adjacent end of the shaft carries a hand wheel 444 having suitable index lines to co-operate with a pointer 446 fastened on the housing. The other end of the shaft 436 has keyed to it a ratchet wheel 448 for slow actuation of the worm. A bracket 450 is fastened by screws to the housing 406 and supports a sector-shaped cylinder 452 having the end caps 454. Fluid pressure is supplied to the cylinder through pipes 458 in order to actuate a vane 456 which is keyed to a rock shaft 460. A dog-carrying arm 462 is keyed to the rock shaft and carries a spring pressed pawl or dog 464 engaging the teeth of the ratchet wheel 448. The dog is connected to a knob 466 having a lug 468 normally fitting in a notch of the arm 462 but the lug can be withdrawn from the notch to lock the dog away from the ratchet wheel. Thus it will be seen that, by the actuation of the vane, a slow feed movement can be imparted through the ratchet wheel and the worm gearing to the feed screw 394. If a somewhat faster feed is de-

sired, the ratchet dog can be retracted thus permitting rotation of the worm by the hand wheel 444. If still more rapid adjustment of the main slide is desired, the clutch teeth at 424 can be disengaged by turning the threaded collar 430 and then a crank on the squared end of the feed screw provides for quick rotation. The extent of the step by step movement of the ratchet wheel can be adjusted by means of stop screws 469 which are adapted to engage the sides of the vane 456.

Timing mechanism

Figs. 14 and 15 show the timing unit which is driven by an electric motor 470 driving variable speed gearing in a housing 472, the gearing being connected by a coupling 474 to reducing gearing in a housing 476. This gearing is connected by a coupling 478 to a cam shaft 480 journalled for rotation in standards 482. On the shaft is secured a series of cam holders 484 carrying a series of lobed cams 486. These cams are similar but are adjusted into different angular positions by means of arcuate slots 488 in the cams and fastening screws 490 which project through the slots into the cam holders 484. Each cam co-operates with a cam roller 492 revolubly held in a fork 494 at the front of a piston rod 496. One arm of each fork projects or laps by the side of the cam as indicated at 498 to prevent the piston rod from turning. Each piston rod extends into a valve, one valve 500 controlling the vertical cylinder and piston units which reciprocate the work heads, another valve 502 controlling the cylinder and piston units which advance and retract the chucking and ejecting cams, another cylinder 504 controlling the cylinder and piston units which actuate the lower loading cylinders, and another valve 506 controlling the cylinder and piston units which actuate the upper loading cylinders. Each valve comprises two spaced pistons 508 which are urged forwardly by a coil spring 510, thus tending to hold the cam roller 492 against the cam 486. A two-way switch 514 is rockably mounted in a switch box 516 and controlled by a lever 518 having a cam roller 520 adapted to engage one of the cams 486. A coil spring 522 connected to the lever and to a supporting bracket tends to hold the roller 520 against its cam.

Manual control of dressers and feed of main slides

In Figure 16 is shown a manual control valve 524 which controls the dressing mechanism and the in-feed of the main slides. The valve body is mounted on a bracket 526 fastened to the front of the main frame and is provided with a piston rod 528 with a fork 530 at the end. The fork carries a pin 532 riding in a slotted arm 534 which is keyed to a rock shaft 536 having an operating handle 538. The handle normally takes the position indicated in Figure 16 under the influence of gravity but, when it is desired to actuate the dressing mechanism, the handle is raised until it abuts against a stop screw 540. The raising of the handle reverses the direction of fluid pressure in the cylinder and piston units 90 and 176 which control the dressing mechanism and in the sector shaped units 452 which actuate the main slides, as will appear.

Diagram of electrical and fluid pressure connections

Referring to Figure 2, a three-phase wiring system provides line wires leading to a series of switches. One switch 550 starts and stops the motor M which drives the grinding wheel. Another pair of switches 552 control the motors 324 which run the work spindles. Another switch 554 controls the motor 470 which drives the timing unit. Another switch 556 controls the four magnetic clutches 272, one wire 560 from the switch having branches leading to corresponding terminals of the four magnetic clutches, another wire 562 leading to the two-way switch 514. This switch is connected by a wire 564 having branches to the upper magnetic clutches, another wire 566 from the switch having branches leading to the lower magnetic clutches.

In the fluid pressure diagram, the letters P and E indicate those pipes in which pressure fluid and exhaust fluid, respectively, always exist. In those pipes indicated by the letters P′ and E′, the pipes contain pressure fluid and exhaust fluid, respectively, when the parts are in the position indicated in the diagram but these pipes are adapted to have the fluid and exhaust reversed for the actuation of the cylinder and piston units as will appear.

Assuming the parts are in the positions indicated by the diagram and by Fig. 7, the upper pairs of cams 350 and 352 are held in their advanced or operative positions while the lower pairs of cams are held in their retracted or inoperative positions. All four of the loaders 364 are held retracted and the work heads 248 are in the down position. The work-pieces W on the two upper spindles are in the finished position, that is, ground to size, and new work-pieces are already applied to the lower work spindles. The timing mechanism actuates the valve 500 and so reverses the course of fluid in cylinders 302 to raise the work-heads. When the buttons 212 ride along the cams 350, the chuck control rods are advanced to release the work and immediately thereafter, the other buttons 234 engage the cams 352 and are thereby actuated to eject the work. Each upper button 234 passes above and off of its cam 352 so that the ejectors are retracted by spring pressure while each button 212 remains for a time on its cam ready to clamp a new piece when the latter is advanced by its loader. Next the timing mechanism actuates the valve 506 so that fluid pressure is reversed at the upper loading cylinders 358. The upper loaders 364 advance to transfer new work from the magazines 372 to the upper spindles and are almost immediately retracted when the stem of the valve 506 is released by the cam of the timing mechanism. The timing mechanism also actuates the valve 502, thereby reversing the flow of fluid at the cylinders 342 and so causing the upper cams 350 and 352 to be retracted while the lower ones advance. The buttons 212 which control work clamping are thus released and spring pressure causes the new work to be clamped. Meanwhile the work on the lower spindles is ground to size. The timing mechanism then releases the stem of the valve 500 to reverse the flow of fluid at the cylinders 302 so that the work heads 248 descend. The lower pairs of buttons 212 and 234 are actuated when they reach and ride along the advanced lower pairs of cams 350 and 352 and thus the finished work on the lower spindles is released and ejected. Next the timing mechanism actuates the valve 504 which controls the lower loading cylinders and new work is applied to the lower spindles, etc. Whenever new work is ap-

plied to the spindles, the magnetic clutches **272** operate to release the spindle driving pulleys under control of the switch **514** and the timing mechanism. The cycle is repeated automatically as long as there is work in the magazine or until wear of the grinding wheel calls for an in-feed of the work heads because of insufficient grinding or because of a need to true the form of the wheel.

Truing of the wheel and in-feed of the main slides to compensate therefor and for wheel wear are controlled manually by the valve **524**. (See Figs. 2 and 16.) The valve **524** is shown in the normal position which it occupies while the machine is grinding. Pressure fluid has access to each of the sector-shaped units **452** at that side of the vane which will hold the vane at the end of an active feed stroke of the ratchet wheel **448**. Pressure fluid holds the piston in the cylinder **176** at the end of its idle stroke and holds the piston in cylinder **90** in the position where the dresser slide **80** is in its forward or inoperative position. Upon lifting the handle **538** (Fig. 16) until it meets the stop screw **540**, the flow of fluid is reversed, thus moving the vanes in cylinders **452** on their idle or retracting stroke while the piston in cylinder **176** is actuated to cause a feed stroke of the ratchet mechanism (Figs. 3 and 4) which feeds the entire dressing mechanism downwardly and radially of the wheel. Also, the piston in cylinder **90** is actuated in a direction to move the dressing diamond **60** across the wheel but this last movement does not occur until the down feed stroke is finished because the resistance is greater. When the dresser slide **80** is seen to have completed its dressing stroke, the handle **538** is released and its weight throws the valve back to the Fig. 2 position. This reverses the course of fluid at the units **452** and so causes an active stroke of the vanes, thereby feeding in the main slides **312** horizontally to compensate for the vertical down-feed of the dresser. The pistons in the cylinders **90** and **176** are also reversed, the piston which controls the diamond slide **80** being spring pressed to its starting position and the other piston making an idle return stroke by fluid pressure.

I claim:

1. In a machine of the character described, a grinding wheel, a work head having a plurality of work holding members, means for causing relative reciprocation between the work head and the wheel in a direction to cause a work piece and the wheel to engage by relative movement along a line which is substantially tangent to the peripheral curve of the wheel while another work piece and the same wheel become separated, and means for reloading each work holding member when it is separated from the wheel; substantially as described.

2. In a machine of the character described, a grinding wheel, a work head having a plurality of work holding members, means for causing a relative shifting movement of the work head and the wheel in a direction to cause an unfinished work piece to engage the wheel substantially tangentially while a finished work piece and the wheel become separated, means for replacing the finished work piece with a new piece while grinding the unfinished piece, and means for reversing the direction of shifting movement to cause the new piece to engage the same wheel; substantially as described.

3. In a machine of the character described, a grinding wheel, a plurality of work heads arranged at separated points angularly spaced about the wheel periphery and each comprising a pair of work holding members, and means for shifting the work holding members of each pair as a unit along a path which will carry the work substantially tangentially of the wheel; substantially as described.

4. In a machine of the character described, a grinding wheel, a work head having a pair of parallel work spindles, means for rotating the spindles, and means for causing a relative reciprocating movement between the wheel and the work head in a direction to cause one spindle and the wheel to approach while the other spindle and the wheel separate; substantially as described.

5. In a machine of the character described, a grinding wheel, a work head having a pair of parallel openings therein, a work spindle rotatably mounted one in each opening, work holding means on each spindle, and means for shifting the work head with respect to the wheel to bring the pair of work holding means alternately into proximity to the wheel; substantially as described.

6. In a machine of the character described, a grinding wheel, a work head, means for shifting the work head in a direction to move the work substantially tangentially with respect to the curved periphery of the wheel to feed the work gradually to the wheel, and means for moving the work head radially of the wheel to compensate for reduction in diameter of the wheel; substantially as described.

7. In a machine of the character described, a grinding wheel, a work head, a support for guiding one of said first named members, means for shifting said one member along the guiding support to cause a work piece and the wheel to engage substantially tangentially with respect to the curved periphery of the wheel, a slide carrying said support, the slide and the support being arranged in planes at right angles to one another, and means for feeding the slide in a direction to cause radial movement of approach between the wheel and the work head to compensate for reduction in diameter of the wheel; substantially as described.

8. In a machine of the character described, a grinding wheel, a work head, a support for guiding the work head, means for shifting the work head along the guiding support to feed a work piece tangentially into the wheel, a main slide, a pivoted connection between the main slide and said support, and means for feeding the main slide to move the work piece radially of the wheel to compensate for reduction in diameter of the wheel; substantially as described.

9. In a machine of the character described, a grinding wheel, a work head, a support for guiding the work head, means for shifting the work head along the guiding support to feed a work piece tangentially with respect to the peripheral curvature of the wheel and in the plane of the wheel, and a pivotal mounting for the support, the axis of the pivotal mounting being in a line which is substantially tangent to the wheel; substantially as described.

10. In a machine of the character described, a grinding wheel, a work head having a pair of spindles, driven pulleys for the spindles, an idler roller partially entering between the pulleys, a belt looping around the puleys and passing between each pulley and the idler roller, and a

motor yieldably mounted with respect to the work head to provide for a relative movement between the spindles and the motor; substantially as described.

11. In a machine of the character described, a grinding wheel, a work head having a pair of work spindles, a support for the work head, means for reciprocating the work head on the support, a motor, a driving connection between the motor and the work spindles, and means for yieldably mounting the motor on the support to provide for said reciprocation of the work head; substantially as described.

12. In a machine of the character described, a grinding wheel, a work head having a pair of spindles, a support for the work head, means for reciprocating the work head and its spindles as a unit on the support, driven pulleys for the work spindles, a driving pulley on the support, means for urging said driving pulley away from the spindles, and a belt looped around the driving pulley and the driven pulleys; substantially as described.

13. In a machine of the character described, a grinding wheel, a wheel head, a work head, a wheel dressing tool mounted on the wheel head, a slide for feeding the dressing tool radially of the wheel to compensate for wear of the wheel, a slide for feeding the work head radially of the wheel at another radius thereof to compensate for the feed of the tool, and means for insuring a feed movement of the dressing tool before the feed of the work head begins; substantially as described.

14. In a machine of the character described, a grinding wheel, a work head, a pair of work spindles rotatably mounted on the work head, a guiding support for the work head, a pair of loading units mounted on the guiding support, and means for reciprocating the work head to bring the work spindles successively into alignment with a loading unit; substantially as described.

15. In a machine of the character described, a grinding wheel, a work head having work holding means and work ejecting means, a support for guiding the work head, means for reciprocating the work head along its support to carry a work-piece into and out of engagement with the wheel, and a pair of cams for actuating the work holding and the ejecting means as the work head reciprocates; substantially as described.

16. In a machine of the character described, a work head having a hollow spindle and a chuck, a sleeve shiftable in the spindle and a rod shiftable in the sleeve to control the chuck, a plunger mounted on the work head, gearing connecting the plunger with the sleeve, and a pair of cams, one to engage the plunger and the other to engage the rod; substantially as described.

17. In a machine of the character described, a work head having a hollow spindle and a chuck, a sleeve shiftable in the spindle and a rod shiftable in the sleeve to control the chuck, a plunger mounted on the work head and offset from the sleeve, gearing connecting the plunger with the sleeve, a pair of cams offset from one another and in line with the rod and the plunger, and means for causing relative shifting of the rod and the plunger with respect to the cams; substantially as described.

18. In a machine of the character described, a work head having a hollow spindle and a chuck to hold a work-piece, a sleeve shiftable in the spindle and having a rack, means actuated by the sleeve to engage the work-piece, a plunger mounted on the work head and having a rack, gearing connecting the racks, and means adapted to engage the plunger for shifting the sleeve; substantially as described.

19. In a machine of the character described, a grinding wheel, a work head, a work spindle rotatably mounted on the work head, a driven member rotatable around the work spindle, a magnetic clutch having collector rings connected to said driven member, a clutch plate splined to the work spindle, and means on the work head for supplying current to the collector rings; substantially as described.

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