

May 12, 1936.

C. C. STEVENS

2,040,449

GRINDING MACHINE

Original Filed June 10, 1931 12 Sheets-Sheet 1

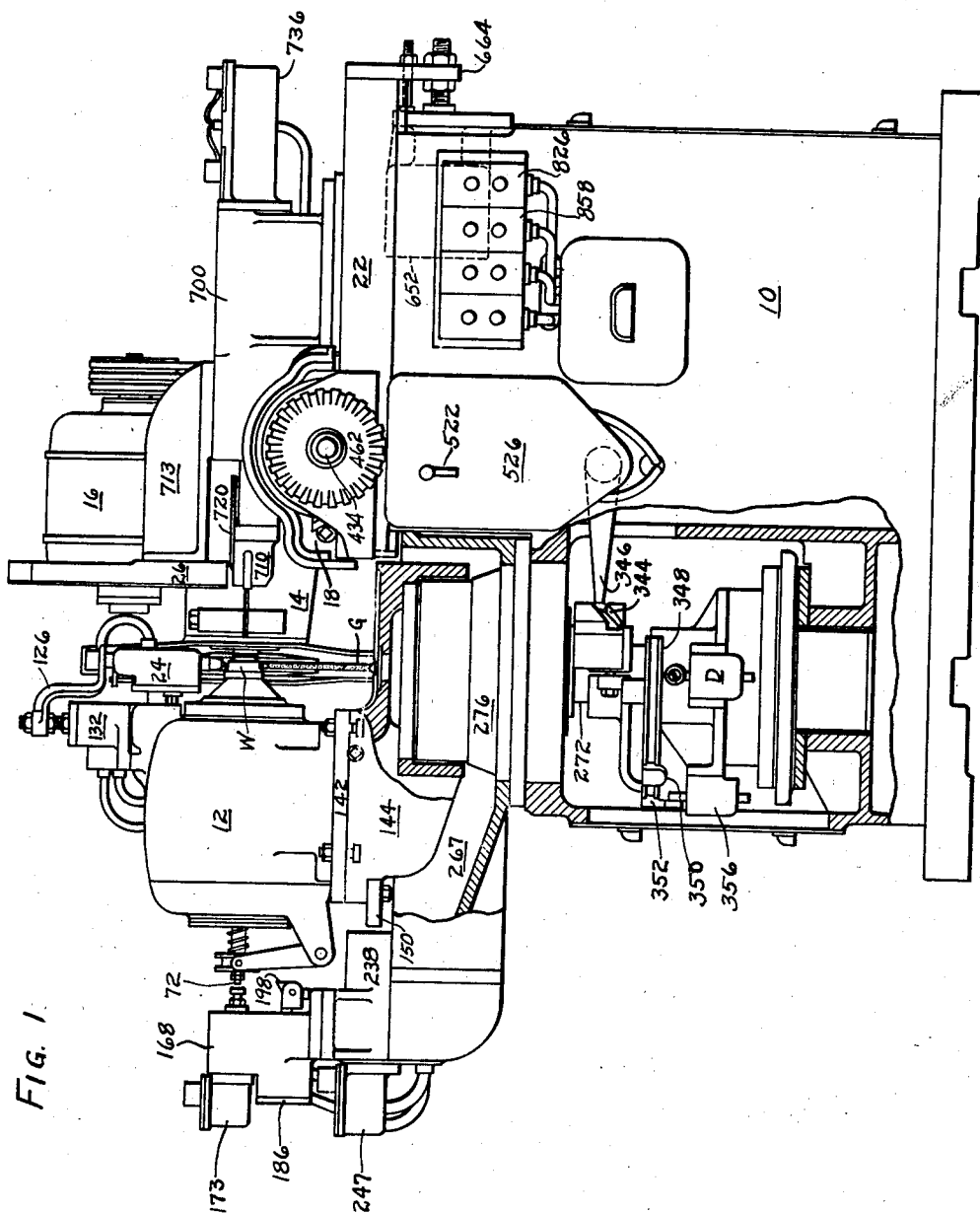


FIG. 1

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May 12, 1936.

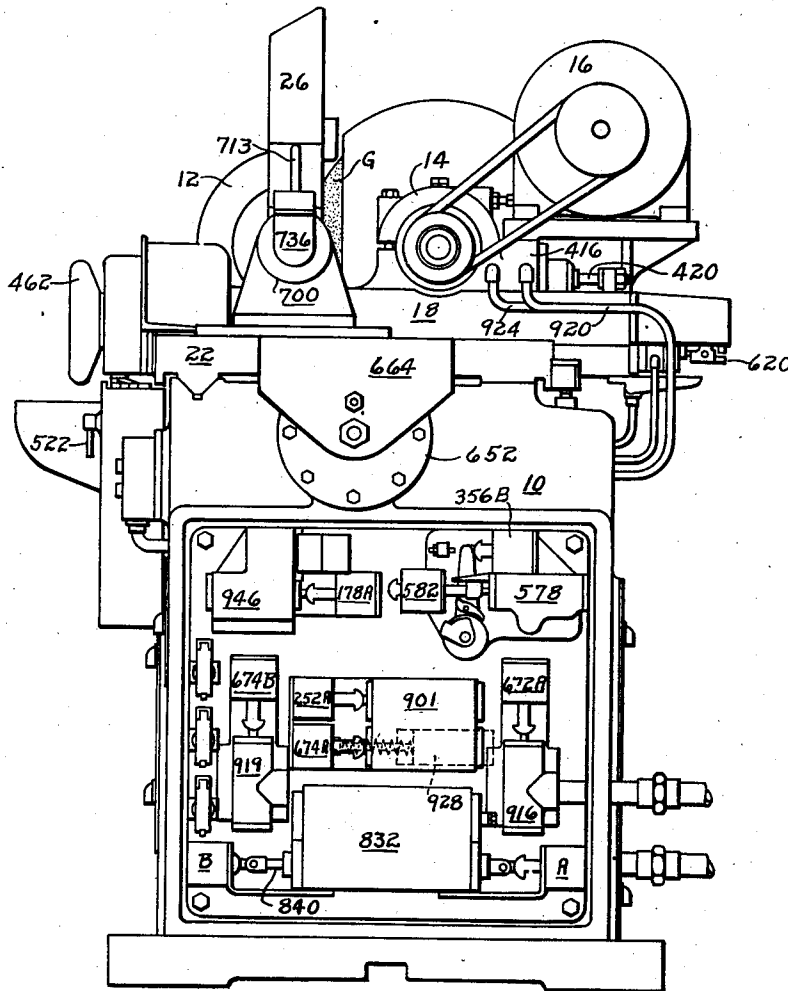
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GRINDING MACHINE

Original Filed June 10, 1931 12 Sheets-Sheet 2

FIG. 2



INVENTOR:
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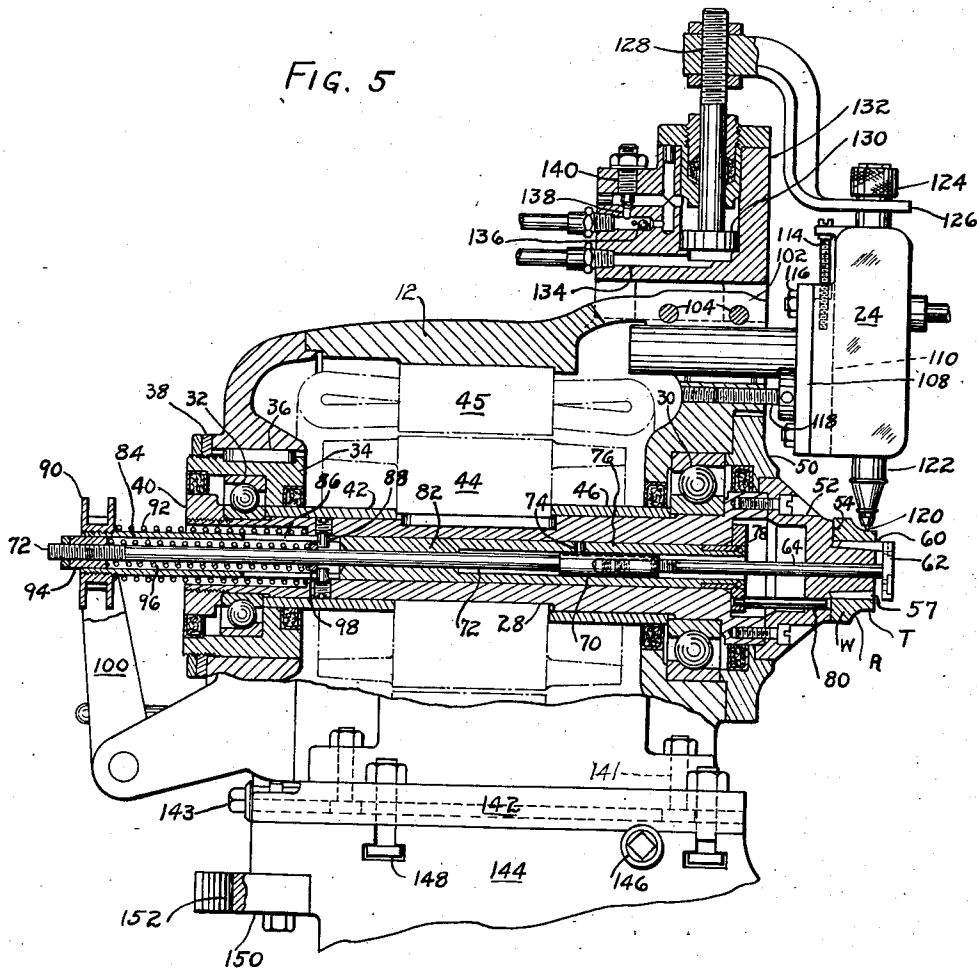
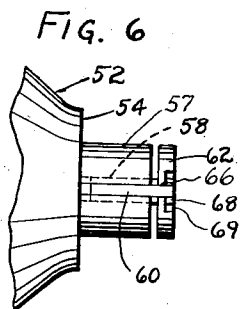
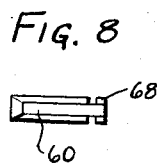
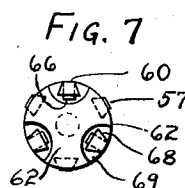
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GRINDING MACHINE

Original Filed June 10, 1931 12 Sheets-Sheet 4



INVENTOR:
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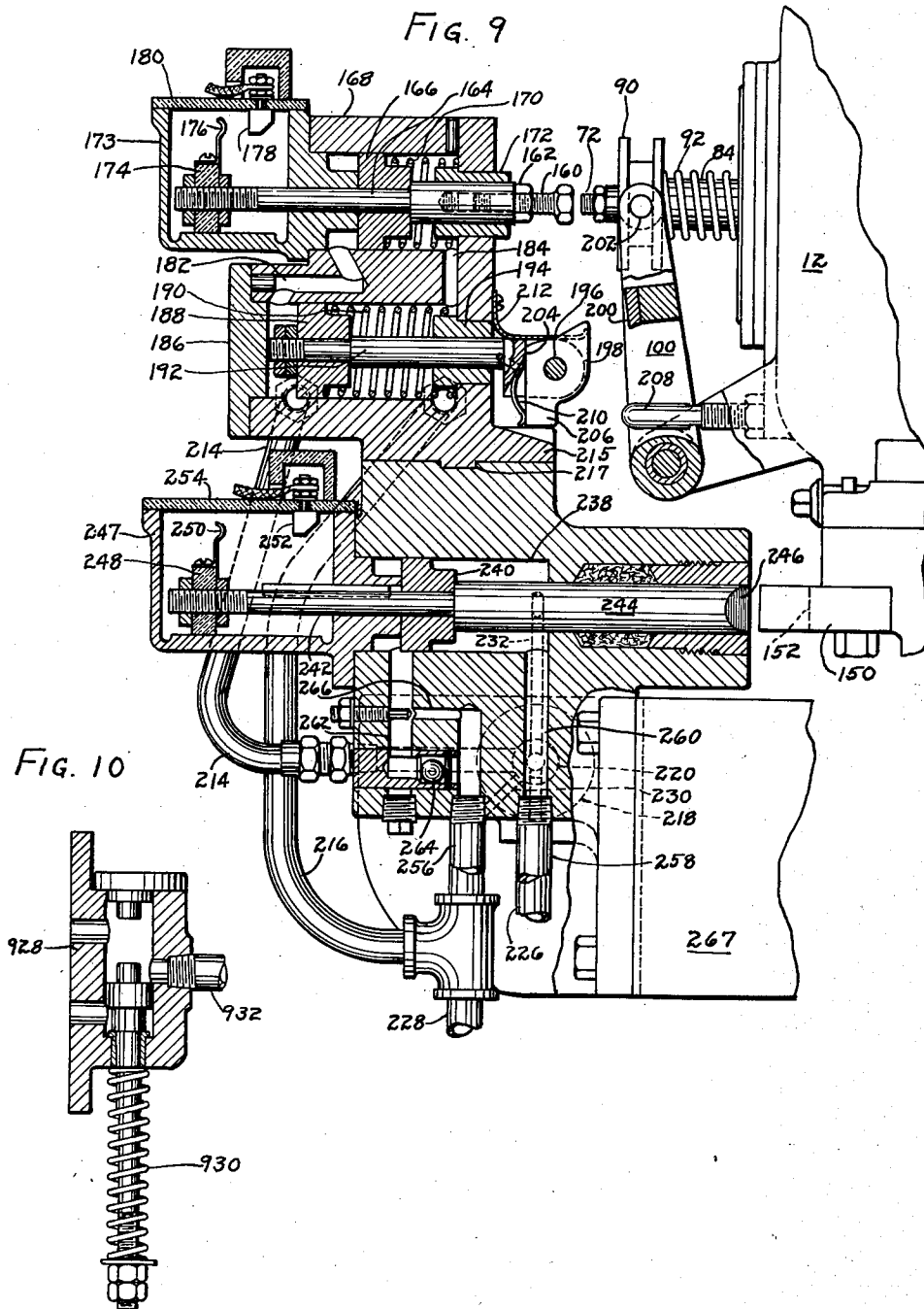
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GRINDING MACHINE

Original Filed June 10, 1931 12 Sheets-Sheet 5



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GRINDING MACHINE

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FIG. 11

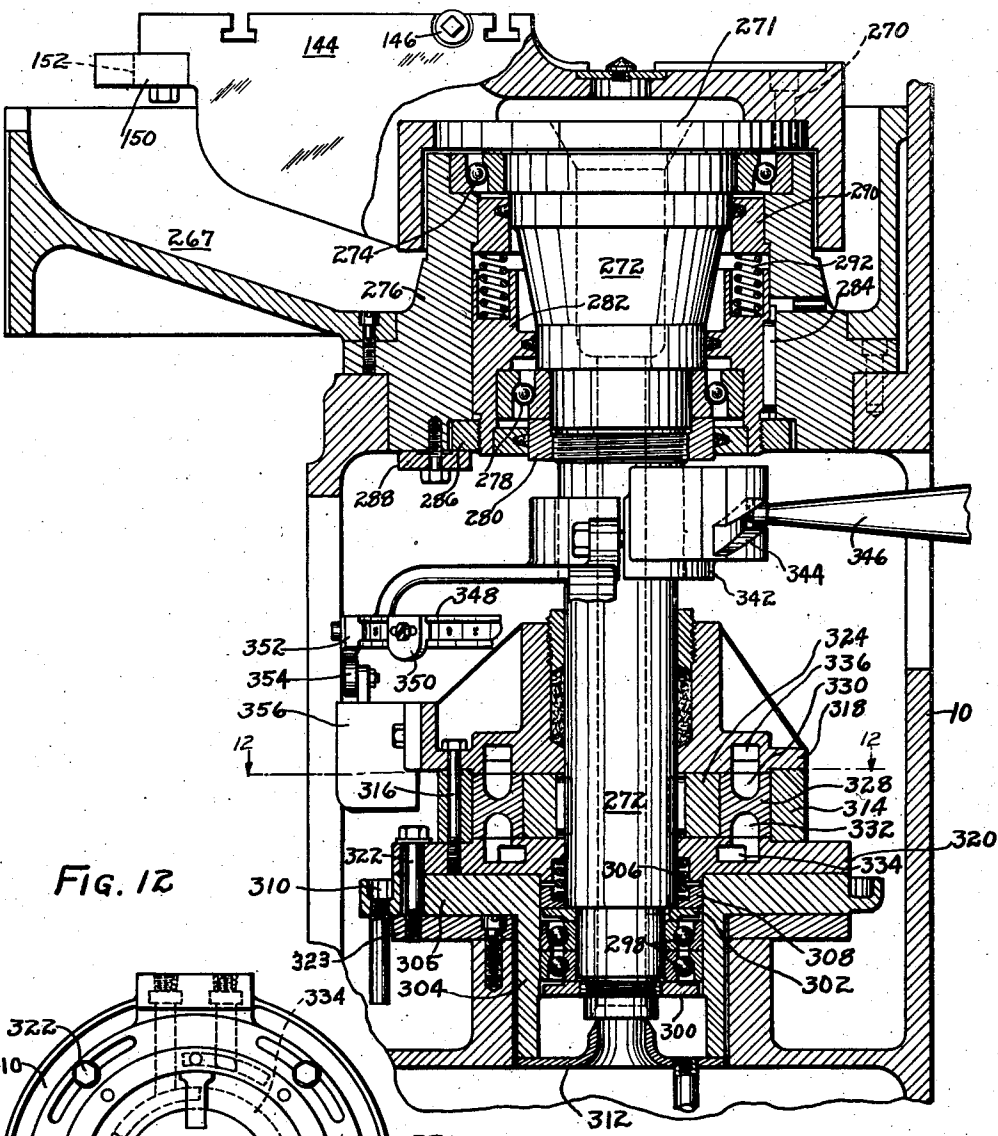
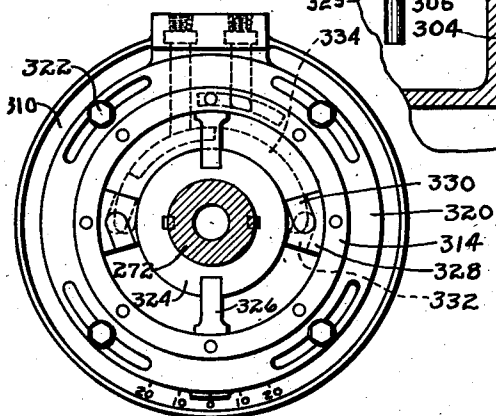


FIG. 12



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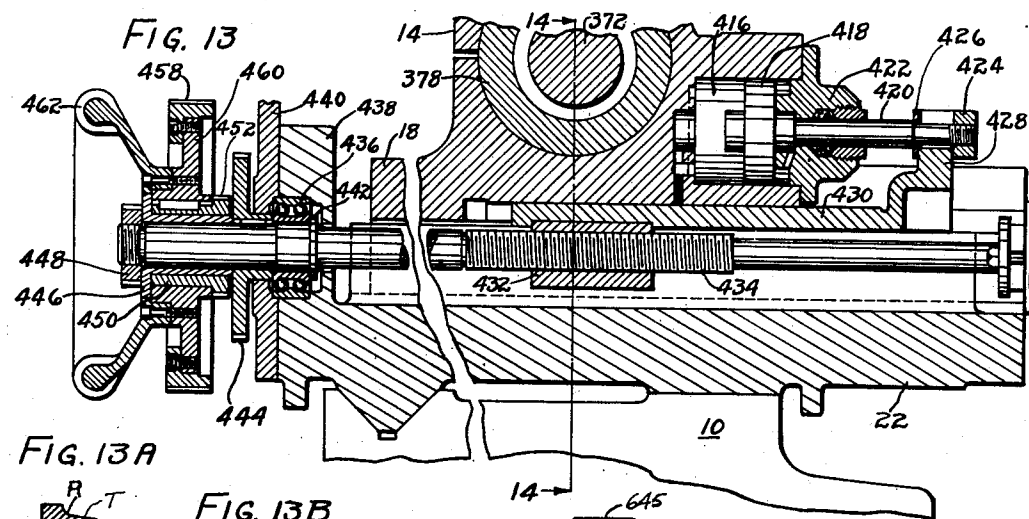


FIG. 13A



FIG. 13B



FIG. 13C

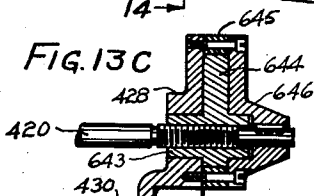


FIG. 13D

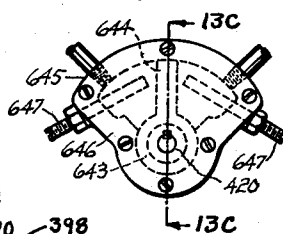
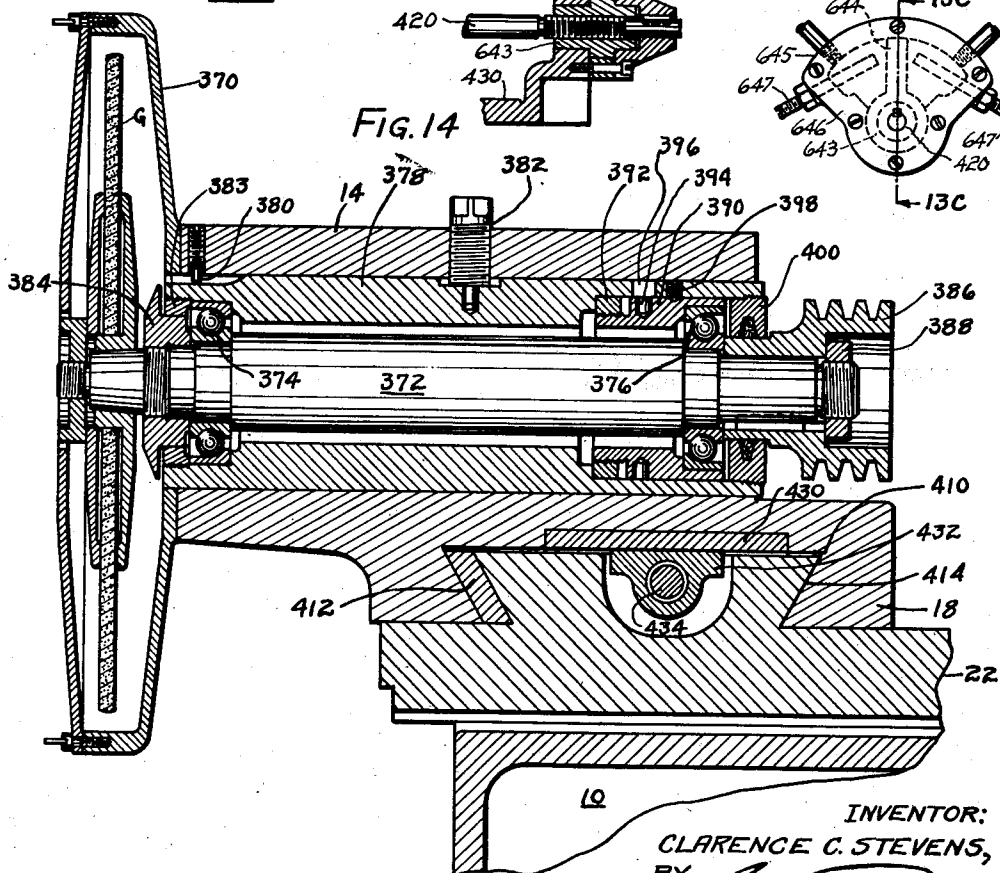


FIG. 14



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FIG. 15

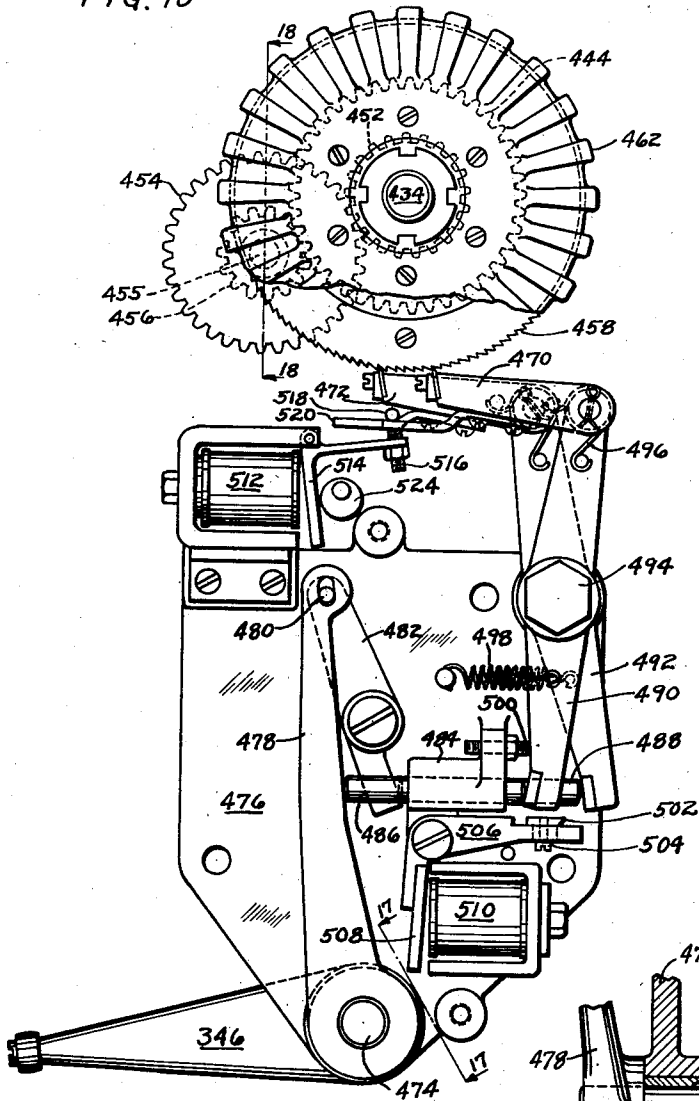


FIG. 16

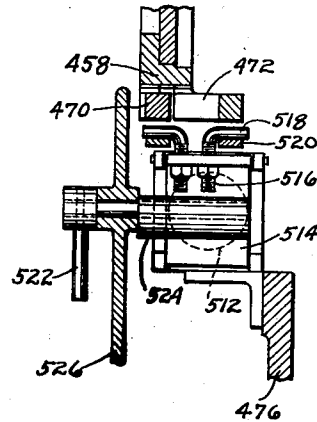


FIG. 17

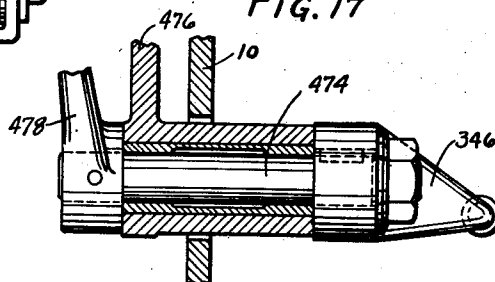
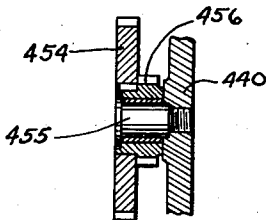


FIG. 18



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GRINDING MACHINE

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FIG. 19

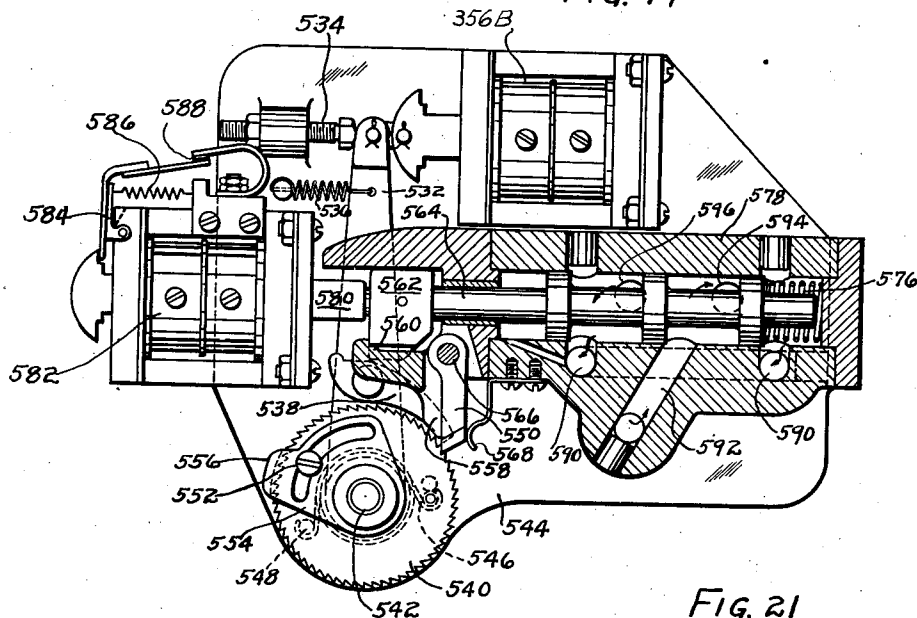


FIG. 20

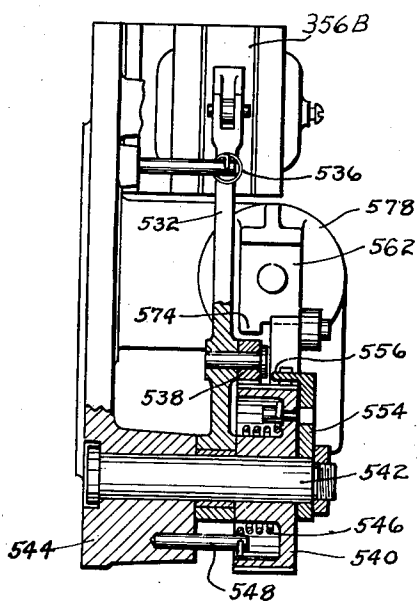


FIG. 21

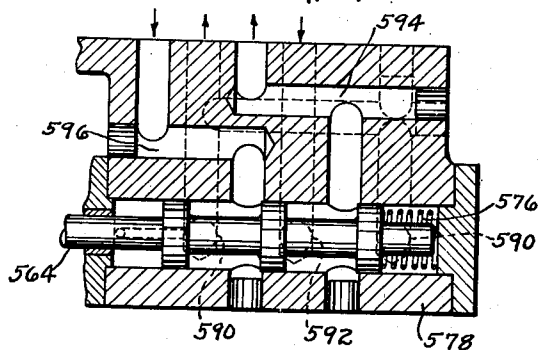


FIG. 22

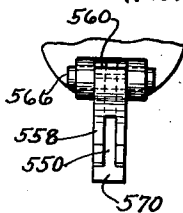
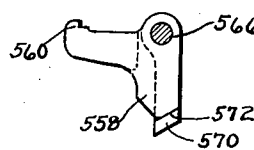


FIG. 23



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GRINDING MACHINE

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FIG. 24

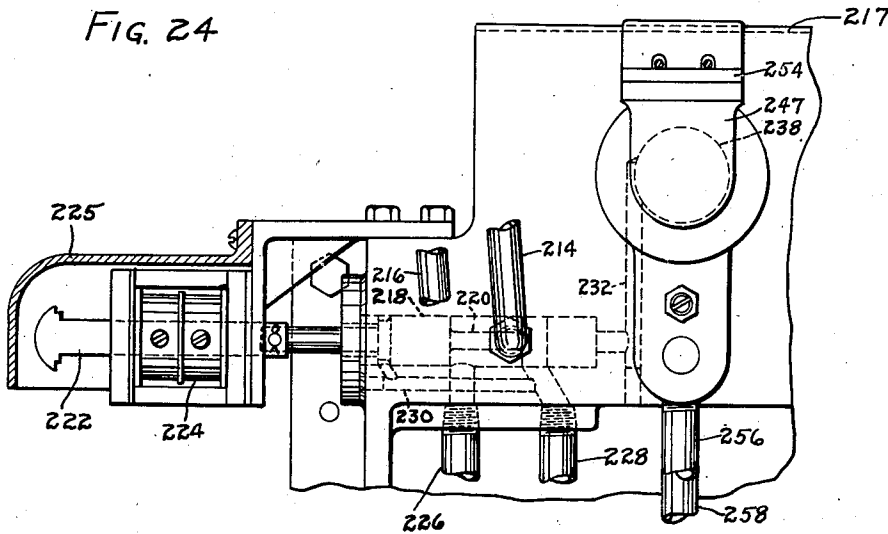


FIG. 25

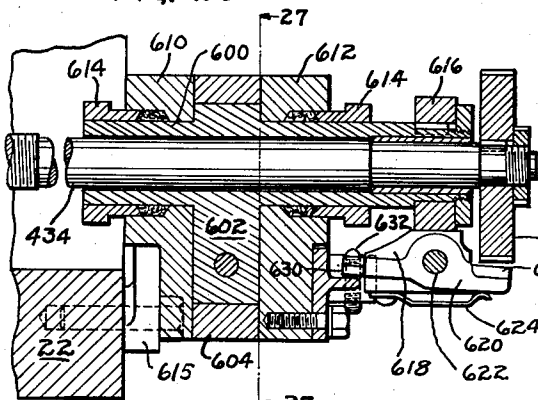


FIG. 27

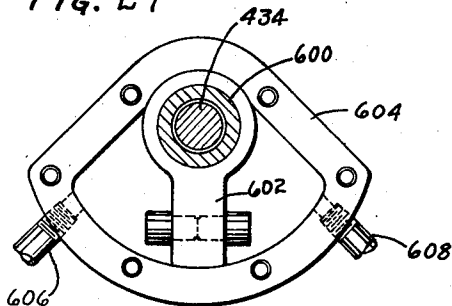


FIG. 26

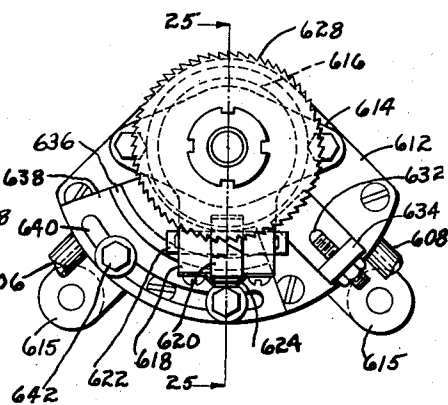
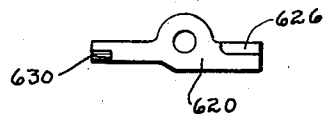


FIG. 28



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GRINDING MACHINE

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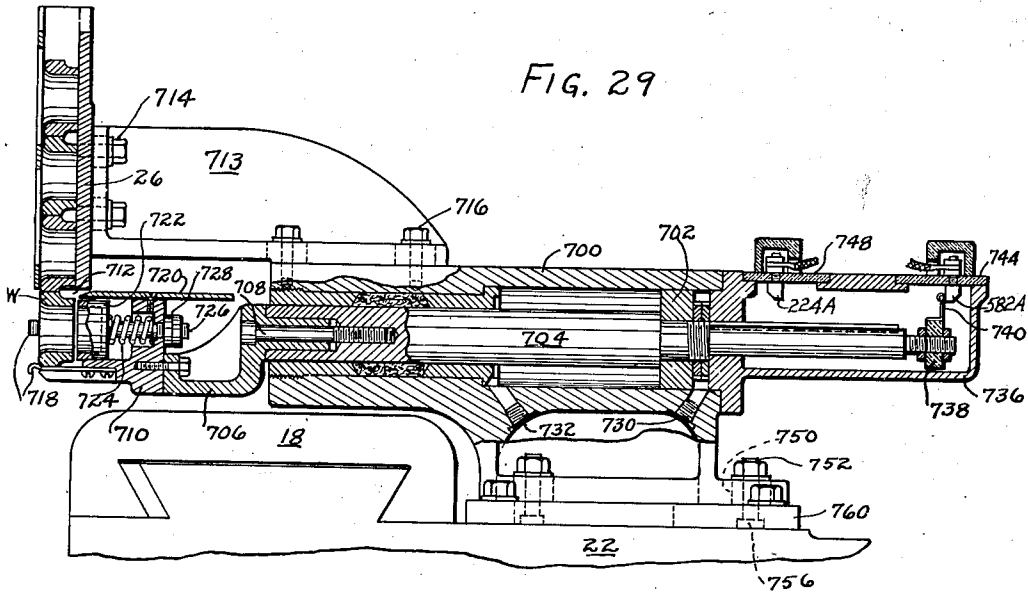


FIG. 30

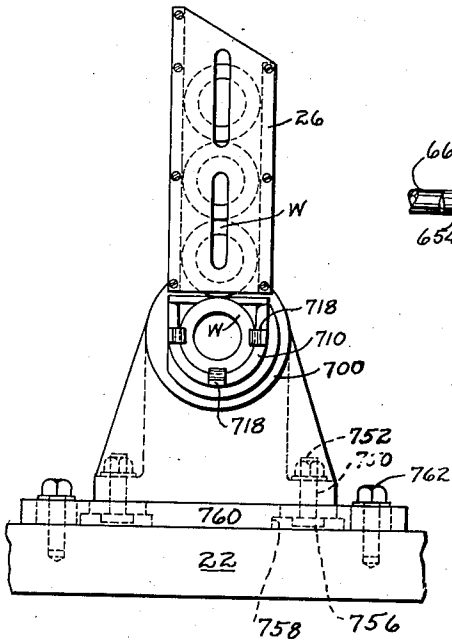
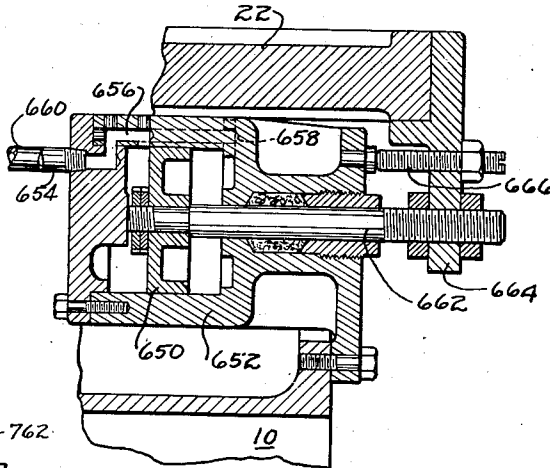


FIG. 31



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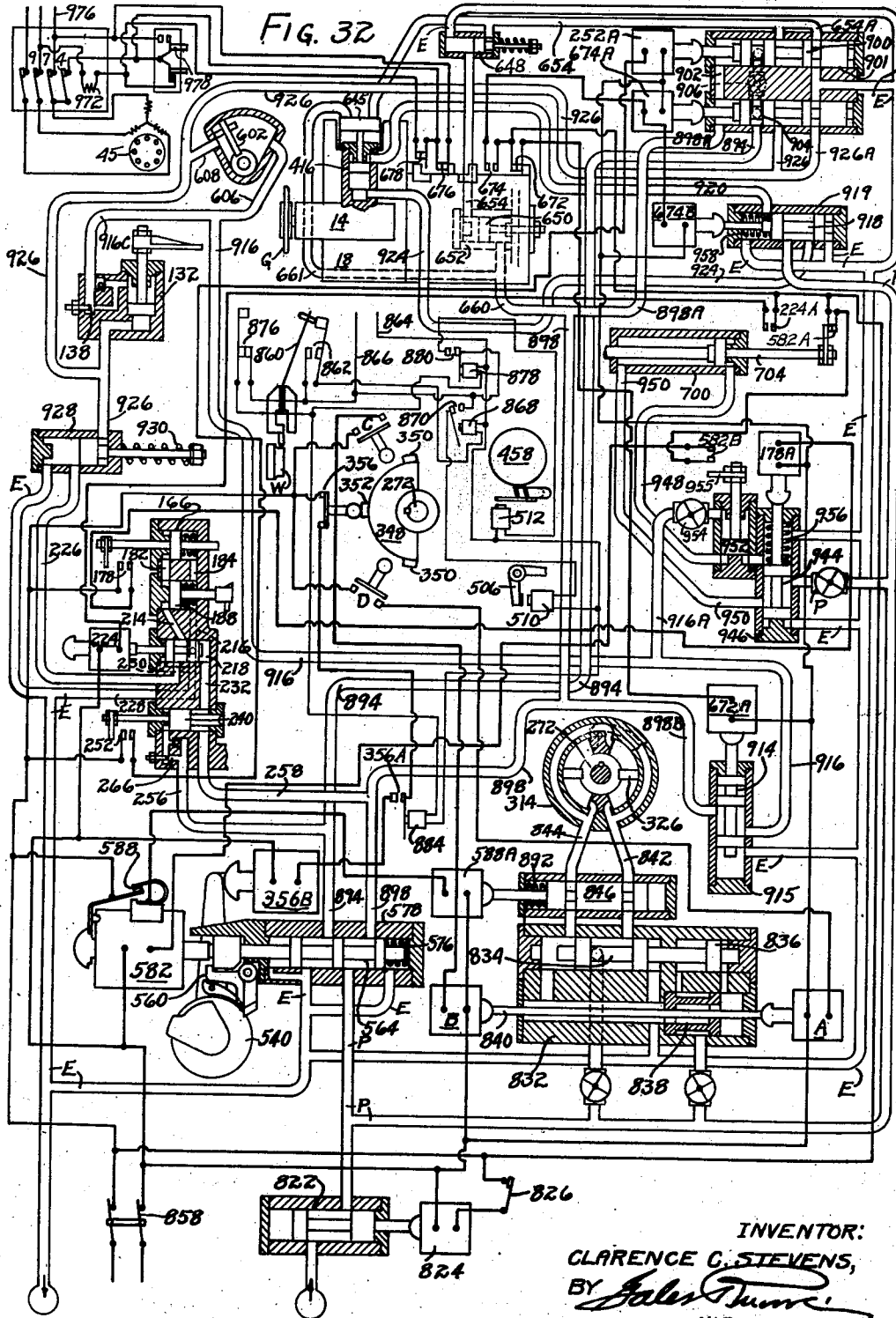
C. C. STEVENS

2,040,449

GRINDING MACHINE

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UNITED STATES PATENT OFFICE

2,040,449

GRINDING MACHINE

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by mesne assignments, to General Motors Corporation, Detroit, Mich., a corporation of Delaware

Application June 10, 1931, Serial No. 543,412

Renewed December 1, 1933

98 Claims. (Cl. 51—97)

This invention relates to grinding machines and comprises all of the features of novelty herein disclosed, by way of example, in connection with an automatic machine for grinding articles such as race rings for bearings.

An object of the invention is to provide an improved oscillating grinding machine. Another object is to provide a grinding machine which is fully automatic and capable of reliable and efficient grinding of articles having both curved and straight surfaces. Another object is to provide improved mechanism for controlling the approaching and separating movements between a work head and a tool head. Still another object is to provide an improved work loading and ejecting mechanism for a work head. Yet another object is to provide improved mechanism for controlling the sequence of operations in an automatic grinding machine. 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

Fig. 1 is a front elevation of the machine with some parts in section.

Fig. 2 is an end elevation.

Fig. 3 is a plan view of a portion of the machine.

Fig. 4 is a rear view of a portion of the main slide.

Fig. 5 is a vertical sectional view of the work head.

Fig. 6 is a plan view of a portion of the chuck.

Fig. 7 is an end view of a portion of the chuck.

Fig. 8 is a plan view of one of the clamping wedges.

Fig. 9 is a vertical sectional view of the chucking, ejecting and locking cylinders.

Fig. 10 is a sectional view of a check valve.

Fig. 11 is a vertical sectional view of the work head oscillating mechanism.

Fig. 12 is a section on line 12—12 of Fig. 11.

Fig. 13 is a vertical sectional view of the cross feed mechanism.

Figs. 13A and 13B are sectional views of workpieces.

Fig. 13C is a sectional view of a modification on line 13C—13C of Fig. 13D.

Fig. 13D is an end view of Fig. 13C.

Fig. 14 is a vertical sectional view of the grinding wheel head.

Fig. 15 is a front elevation of the ratchet feed mechanism.

Fig. 16 is a sectional view of details associated with the feed pawls.

Fig. 17 is a sectional view on line 17—17 of Fig. 15.

Fig. 18 is a sectional view on line 18—18 of Fig. 15.

Fig. 19 is a front view of the counting mechanism with some parts in section.

Fig. 20 is an end view of Fig. 19 with some parts removed and others in section.

Fig. 21 is a horizontal sectional view of the cylinder of Fig. 19.

Fig. 22 is an end view of a latch and pawl.

Fig. 23 is a side view of Fig. 22.

Fig. 24 is a side view of a control valve.

Fig. 25 is a vertical sectional view on line 25—25 of Fig. 26.

Fig. 26 is a rear end view of the feed screw retraction mechanism.

Fig. 27 is a sectional view on line 27—27 of Fig. 25.

Fig. 28 is a side view of a pawl lever.

Fig. 29 is a vertical sectional view of the loader.

Fig. 30 is an end view of the loader.

Fig. 31 is a vertical sectional view of the main slide cylinder.

Fig. 32 is a diagram.

This machine is more especially designed to operate on ball bearing cones to grind thereon an arcuate raceway terminating in a tangent surface. Work-pieces are taken one by one from a magazine by a loader and presented to a chuck, the chuck gripping the work-piece as the loader retreats. The work head begins to oscillate and the grinding wheel advances rapidly towards the work on a cross slide, then a feed screw with pawl and ratchet mechanism advances the wheel first with a coarse feed and then with a fine feed until the feed is stopped under control of a feeler gauge. The work head then continues oscillation for a predetermined number of strokes while the wheel is kept advanced, thereby to produce a smooth finish. The work head is finally locked in a predetermined angular position and the grinding wheel (still advanced) runs out on a main slide at right angles to the direction of cross feed, thereby to grind the tangent surface. The wheel is quickly retracted, the feed screw reverses and the feeler gauge is lifted. The chuck releases the work and an ejector removes it. Suitable cylinder and piston units actuate the various mechanisms under control of valves, solenoids, switches, etc. to insure

the proper sequence and the machine is fully automatic.

The numeral 10 indicates a main frame and 12 indicates the work head which oscillates around a vertical axis while an arcuate surface is ground upon the work-piece W by a grinding wheel G. The wheel spindle is journaled in a wheel head 14 and is driven by an electric motor 16. The wheel head is carried by a cross slide 18 which can be fed from front to rear. The cross slide is also mounted on a main slide 22 for movement parallel to the wheel axis. A feeler gauge 24 measures the work during grinding and a magazine 26 contains a supply of work-pieces delivered one-by-one to the work head by a loader.

Work-head.—See Figs. 5, 6, 7 and 8. The hollow spindle 28 of the work-head is journaled on ball bearings 30 and 32, the outer race ring of bearing 32 abutting against a shoulder in a housing 34 which is held from rotation by a key 36. Adjustment of the housing is effected by a nut 38 engaging the work-head. The inner race ring of bearing 32 is clamped by a nut 40 against a sleeve 42 on the spindle, the sleeve abutting against the rotor 44 of a motor 45 housed in the work-head. Another sleeve 46 engages the inner race ring of bearing 30 and holds it against a shoulder on the spindle. The outer race ring of bearing 30 is clamped in a recess of the work-head by a plate 50. Suitable seals retain lubricant in the bearing.

Secured to the hollow spindle 28 is a chuck 52 having a shoulder 54 to engage one end of the work-piece W while a cylindrical surface has work-guiding inserts 57 to engage the bore. Alternating with the inserts is a series of undercut slots 58 in which wedges 60 are longitudinally adjustable, the wedges being of trapezoidal shape in cross section. The bottom of each slot 58 presents a tapered surface to a corresponding surface on each wedge whereby longitudinal movement of the wedges (to the left in Fig. 5) will cause them to expand and grip the bore of the work-piece. A disc 62 is connected to the larger ends of the wedges and is operated by a pull rod 64 extending through the hollow spindle. The disc has a series of parallel sided slots 66 fitting necked down surfaces on the wedges, the resulting heads 68 on the wedges occupying recesses 69 in the disc.

The pull rod 64 is threaded at the end into a head 70 on an operating rod 72, a pin 74 projecting from a guide sleeve 76 into a slot of the head so that the rod will rotate with the spindle. The sleeve 76 is slidable in the hollow spindle and carries a flanged collar 78 provided with a set of ejector pins 80 which pass through the chuck 52 to knock-off the work. The sleeve 76 has a thickened portion 82 to guide the rod 72 and has a thin tubular extension 84 which is slotted at 86 to receive pins 88 projecting from the hollow spindle, thus to permit sliding of the sleeve while compelling it to rotate with the spindle. A grooved collar 90 is fixed to the end of the sleeve and a spring 92 is interposed between the collar and an abutment face in the spindle to produce a tendency to retract the ejector pins. A nut 94 is threaded on the rod 72 and a coil spring 96 is interposed between the nut and a washer 98 abutting against the pins 88. The spring thus pulls on the rod to produce the gripping force for the chuck wedges. As will appear, a piston rod engages the end of the rod 72 to release the work and arms 100

are actuated to move the collar 90 to operate the ejector.

Gauge.—See Fig. 5. The work-head is split at 102 and is provided with clamping screws 104 to clamp a stud carrying a guide plate 108. The plate has a tongue 110 furnishing a guideway for the gauge housing 24 which is vertically adjusted by a screw 114. The housing is normally fixed in its adjusted position by clamping nuts 116. The head of an adjusting screw 118 abuts against the guide plate 108 to accurately locate the gauge housing so that its diamond feeler 120 will register with the desired portion of the work. The feeler is carried by a plunger 122 movable vertically through the gauge housing and actuating therein certain electric contacts which control functions of the machine. The details of the gauge are immaterial to the present invention but will appear more fully in a diagram hereinafter described. The plunger has a head 124 by which the feeler is lifted to inoperative position, as when loading and unloading the chuck. A forked arm 126 straddles the plunger below the head, the arm being secured by clamping nuts to the threaded end of a piston rod 128 having a piston 130 in a cylinder 132. Pressure fluid is admitted through a passage 134 to raise the piston. Exhaust fluid from above the piston goes out through suitable ports past a ball check valve 136. When the flow of pressure fluid is subsequently reversed, the ball check valve closes but the fluid will enter slowly through a throttling passage 138 controlled by a screw 140. This provides for the easy engagement of the feeler with the work, the forked arm 126 moving away from the head 124 as soon as the feeler is in contact with the work. The mechanism inside the gauge housing is similar to that shown in patent to Hughes 1,893,205, granted January 3, 1933; it appears diagrammatically in Fig. 32 and will be later referred to.

The work head is adjustable axially on a cross slide 142 by a screw 143 and then bolted by bolts 141 in the desired position depending on the nature of the work. The cross slide 142 is supported on a carrier 144 which oscillates around a vertical axis. The work-piece W, as illustrated, is a ball bearing cone having an arcuate race surface R merging with a tangent surface T. To locate work of different sizes so that the center of the arc will be in the axis of oscillation, the cross slide 142 can be adjusted on the carrier by a screw 146 and is clamped in adjusted position by T-headed bolts 148. The carrier supports an adjustable latch plate 150 provided with a V-shaped locking notch 152 for a lock hereinafter described which holds the work head in a predetermined angular position during loading and unloading and during the traverse of the grinding wheel along the tangent surface T.

Chuck and ejector operating means.—See Figs. 9 and 24. When the work head is stopped, the chuck operating rod 72 lies opposite to the head of a screw 160 adjustably secured by a nut 162 to the enlarged end of a piston rod 164. The rod has a piston 166 in a cylinder 168 and a coil spring 170 retracts the piston, the enlarged end of the piston rod being guided in a bushing 172. At the other end of the piston rod, in a casing 173, is adjustably secured a block of insulation 174 carrying a contact spring 176 arranged to engage and close switch contacts at 178, the contacts at 178 and their binding posts being carried by an insulating cover 180. Advance of the piston

to close the contacts and to release the work is effected by admission of pressure fluid through a port 182, another port 184 at the other side of the piston always being connected to an exhaust line.

5 The pressure fluid comes from an ejector cylinder 186 having a piston 188 which is pressed to inoperative position by a coil spring 190. The piston 188 is carried by a piston rod 192 guided in a bushing 194. The piston rod has a bifurcated

10 head provided with a pivot pin 196 on which is pivotally suspended a lever 198. The lever is arranged to engage a wear plate 200 carried on a cross bar connecting two parallel arms 100 provided with studs 202 entering the groove of

15 collar 90. The lever has a straight surface 204 engaging an abutment so that the lever cannot swing counterclockwise. As the piston 188 advances, the lever 198 engages the wear plate 200 and swings the arms 100 to operate the ejector.

20 The piston 188 advances when the chuck piston 166 advances but is initially spaced from the wear plate so that ejection occurs just after the chuck releases the work. As the lever 198 advances, a depending arm 206 thereon engages an abutment

25 pin 208 so that the lever thereafter rocks clockwise on its pivot to bring the upper end of the lever below the wear plate. The arms 100 and collar 90 thereupon snap back under the power of the coil spring 92. Whenever the piston 188

30 returns, the lever 198 can wipe back under the wear plate 200, a leaf spring 210 yielding to allow clockwise swinging of the lever and thereafter holding the straight surface 204 against its abutment. Another leaf spring 212 engages a flat

35 face on the head of the piston rod 192 to prevent rotation thereof. Pressure fluid enters the cylinder 186 through a pipe 214 and the other end of the cylinder is always connected to an exhaust line through a pipe 216. The cylinders 168 and

40 186 are preferably cast as a unit with both axes at a small angle to their base plate 215 as shown in Fig. 3 so that the piston rods will be parallel to the work head when the work head is locked at the same angle to the axis of the grinding

45 wheel. This is to provide for grinding of the tangent surface T at a slight angle. If it is desired to grind the tangent T at a different angle, sufficient alignment is obtained by sliding the base plate 215 laterally on a guideway 217 and

50 locking it by bolts passing through slots in the base plate.

Control valve for chuck and ejector.—See Figs. 9 and 24. As appears in Fig. 24, the pipe 214 is always in communication with a cylinder 218 at the space where a valve stem 220 connects two pistons. Outside of the cylinder, the valve stem is connected to a plunger 222 adapted to be moved to the right by a solenoid 224 in a casing 225. In the position shown, fluid pressure can

55 enter the valve cylinder through a pipe 226 and go through pipe 214 to the chuck cylinder and ejector cylinder, and pipe 216 is always open to an exhaust line. The left end of cylinder 218 is always in communication with an exhaust pipe

60 228 through a passage 230 and this passage also has a port communicating with the valve cylinder at a point opposite to the right hand piston. When the solenoid is energized, the left hand piston blocks off the pipe 226 and the valve puts

70 the pipe 214 in communication with the exhaust pipe 228. This will allow the coil springs to retract the pistons in the chuck cylinder and in the ejector cylinder. The right hand end of the cylinder 218 has a port 232 leading to another

75 cylinder and when the solenoid acts, this port is

open to an exhaust line as will appear. When the valve is to be restored to its left hand position, the port 232 is in communication with a pressure line and the piston valve is forced back.

Lock mechanism for positioning and locking work head.—See Fig. 9. A lock operating cylinder 238 contains a piston 240 on a piston rod 242 which has an enlarged portion forming a locking

5 plunger 244 having a bevelled end 246 arranged to advance into the notch 152 of the latch plate 150. The work head stops oscillation in approximately the exact position desired but the bevelled end 246 will act as a cam to insure its correct

10 location and lock it in position. The piston rod 242 is keyed from rotation and extends into a casing 247 where it adjustably carries a block of insulation 248 supporting a contact spring 250. The contact spring is arranged to engage and close switch contacts at 252 which are supported

15 on an insulating cover 254. Pressure fluid is admitted to the locking cylinder 238 through pipes 256 and 258 alternately. Pressure fluid goes from the pipe 258 and through a passage 260 to retract the lock quickly, exhaust occurring through a

20 port 262 and past an open ball check valve 264 to pipe 256. When pipe 256 admits pressure fluid, the ball check valve closes and the fluid is slowly admitted through a throttling passage 266 controlled by an adjusting screw. The resulting

25 slow forward movement of the locking plunger 30 provides time for the bevelled end 246 to turn the work head, if need be, to the exact position desired. As above stated, the locking cylinder 238 is connected to one end of the control valve cylinder 218 by the port 232 so that whenever the

35 locking piston is retracted, the control valve is retracted. The four cylinders last described are all carried by a casting which is bolted to a pan 267 which is rigidly secured with respect to the frame 10.

Oscillation of work head.—See Figs. 11 and 12. The carrier 144 which supports the work head is secured by bolts 270 to a flange 271 on the upper end of a hollow rock shaft 272. The shaft is journaled for oscillation on a ball bearing 274 whose outer race ring is supported in a

45 recess of a hollow casting 276 which is bolted to the frame 10. Another ball bearing 278 has its inner race ring locked against a shoulder on the shaft by a nut 280. The outer race ring engages a shoulder in a bearing housing 282 which is slidably adjustable in the hollow casting 276 and held from rotation by a key 284. A

50 nut 286 is threaded on the housing 282 and engages the casting 276 to put an initial load on the bearings. The nut is held by a locking plate 288. A flanged washer 290 carrying a packing is held up against a shoulder in the casting 276 by coil springs 292. The rock shaft 272 is rockably supported at its lower end in a pair of ball bearings 298 whose inner race rings are held on the

55 shaft by a nut 300, a washer 302 being interposed between one of the rings and a shoulder on the shaft. When assembled, these bearings are under an initial load and the outer race rings have a sliding fit in a sleeve 304 having a supporting

60 flange 305. A coil spring 306 presses a washer 308 against the washer 302 to seal the bearings. The flange of sleeve 304 has a fluid collecting groove 310 leading to a drain pipe. A closure

65 plate 312 covers the lower ends of the bearings and has a hole leading to the hole which extends through the rock shaft so that electric wires may be passed up conveniently to the work head.

A cylinder 314 is secured by screw bolts 316 75

between an upper cylinder head 318 and lower cylinder head 320, the latter having arcuate slots traversed by clamping bolts 322 to clamp the cylinder in angularly adjusted position on a plate 323 supporting the flange 305. A sleeve 324 is keyed to the rock shaft inside the cylinder and carries two vanes 326 for rocking the shaft. There are two partition blocks 328 fixed in the cylinder and provided with upper ports 330 and lower ports 332 which conduct fluid pressure alternately to the sides of the vanes under control of a valve. The lower cylinder head has branch passages 334 leading to the lower ports and the upper cylinder head has branch passages 336 leading to the upper ports. When fluid pressure is alternately admitted at the ports 330 and 332, the vanes and the shaft are oscillated.

Fixed to the middle of the rock shaft is a split hub 342 carrying a cam 344 engaging a roller on an operating arm 346. This is the arm which actuates feed pawls as will later appear. The hub 342 also carries an arcuate arm 348 provided with three adjustable dogs of which one end dog 350 and a central dog 352 are shown in Fig. 11. The dogs 350, as will appear, control switches which in turn control a main reversing valve. The central dog 352 engages a roller 354 on a switch enclosed in the casing 356, this switch becoming effective only during a spark-out or polishing action as will appear.

Wheel head.—See Figs. 13 and 14. The grinding wheel G is guarded by a hood 370 attached to the wheel head 14. The wheel is secured to a spindle 372 journaled on ball bearings 374 and 376 carried in a quill 378 which is keyed from rotation by a pin 380 and locked by a screw 382. The outer race ring of bearing 374 is clamped by a nut 383 against a shoulder in the quill and the inner race ring is locked against a shoulder on the shaft by a nut 384. The inner race ring of bearing 376 is clamped to the shaft by a pulley 386 which is secured on the shaft by a nut 388 and driven by a belt from the motor 16. The outer race ring of bearing 376 abuts against a shoulder in a bearing housing 390 which is axially adjustable in the quill. A part of the bearing housing is threaded into a nut 392 which rests against a shoulder in the quill. Before sliding the quill into the head 14, the bearing housing 390 can be turned with the aid of the spanner holes 394 to put an initial load on the bearings. The holes are accessible through a slot 396 in the quill, and the bearing housing is locked by a screw 398. The bearing is sealed by a felt washer in a nut 400.

Wheel head retraction and cross feed.—See Figs. 13, 14, 15 and 18. The cross slide 18 supporting the wheel head has a dovetail slot 410 with a gib 412 at one side of a dovetail guide 414 extending crosswise of the main slide 22. The head carries a jump-back cylinder 416 containing a piston 418 with a piston rod 420 extending rearwardly through a gland 422 and attached by a nut 424 and a washer 426 to a lug 428 on the rear end of a slide plate 430 carrying a feed nut 432 on a feed screw 434. Fluid pressure can be admitted to the cylinder at either side of the piston as will appear and quickly retracts the wheel head or advances it with respect to the slide plate independently of movement of the feed screw. The slide plate occupies a slot in the bottom of the cross slide 18. The feed screw is journaled for rotation without endwise movement by a double row bearing 436 supported in an upright bracket 438 of the main slide 22, the

outer race ring being secured by a plate 440. The inner race ring abuts against a collar 442 on the shaft and is held by a gear 444 and by a flanged bushing 446 which is locked by a nut 448. A sleeve 450 is journaled for rotation around the bushing and carries a pinion 452 at one end to mesh with a gear 454 (Figs. 15 and 18) journaled on a stud 455 and carrying a pinion 456 which meshes with the gear 444, thereby providing reduction gearing for the feed screw. A ratchet wheel 458 is secured to a hub member 460 which is keyed to the sleeve 450. A hand wheel 462 is also fastened to the hub member.

Ratchet feed mechanism.—See Figs. 15, 16 and 17. The ratchet wheel 458 is advanced by a pair of pawls 470 and 472 which receive alternate feed impulses from the oscillating head and the rock arm 346. The arm is secured to a rock shaft 474 journaled in a boss of a bracket 476 on the frame 10 and carrying an arm 478 having a pin and slot connection 480 with a lever 482. A lug 484 on the bracket 476 is bored to provide guides for plungers 486 and 488. The plunger 486 abuts at one end against the arm 478 and abuts at the other end against the lower end of a lever 490. The plunger 488 abuts at one end against the lower arm of lever 482 and abuts at its other end against the lower end of a lever 492. The levers 490 and 492 are pivoted on a stud 494 and their upper ends pivotally support the pawls 470 and 472. A spiral spring 496 is attached to each lever and to one of the pawls to hold the pawls against the ratchet wheel. A coil spring 498 is attached to each lever 490 and 492 and to the bracket 476 to draw the pawls to a retracted position ready to feed. One pawl is retracted as the other advances and hence a feed stroke occurs when the arm 346 swings in either direction. In the retracted position, each lever 490 and 492 rests against an adjustable stop screw 500. The stroke of the pawls can be reduced automatically by interposing a stop in the path of the returning levers 490 and 492. This stop comprises a blade 502 adjustably secured by screws 504 to a lever 506 pivoted on the bracket 476. The lever has one arm provided with an armature 508 adjacent to a magnet 510 so that, when the magnet is energized, the lever will swing the stop blade 502 upwardly to restrict the stroke of the pawls and so reduce the feed. The magnet is desirably controlled by the gauge to reduce the feed a little before the piece reaches final size. To stop the feed entirely when the gauge indicates that the piece is down to size, a second magnet 512 is energized to swing a bent lever 514. One arm of the lever supports screws 516 whose ends 518 are bent to hook around offset plates 520 carried on the feed pawls. Thus the pawls are moved automatically away from the ratchet wheel. The pawls can also be retracted manually by an arm 522 on a shaft carrying an eccentric cam 524 to swing the bent lever 514. The rock shaft is conveniently journaled in a cover plate 526 which encloses the feed mechanism.

Spark-out counting mechanism.—See Figs. 19, 20, 21, 22 and 23. A counting mechanism is provided in order to make the wheel head oscillate a predetermined number of strokes after the feed is stopped and before the wheel is backed away. This is to produce a spark-out or polishing action and contributes to a smooth finish on the work. When the feed stops, the continued oscillation of the work head repeatedly energizes a solenoid 556B and swings an arm 532 which is

returned against a stop screw 534 by a coil spring 536. The arm pivotally carries a pawl 538 engaging a timing ratchet wheel 540 which is loose on a stud 542 secured to a bracket 544 at one end of the machine. A spiral spring 546 is secured to a pin in a recess of the ratchet wheel and is also attached to a pin 548 on the bracket 544. The spring winds up as the ratchet wheel turns and a detent 550 prevents the ratchet wheel from returning. Adjustably secured to the ratchet wheel by a screw 552 is a sector plate 554 carrying a lateral cam or shield 556 arranged to engage an arm 558 on a latch 560 thereby releasing the head 562 of a valve stem 564. The latch is pivoted at 566 and is notched to receive the detent 550 which is pressed towards it by a leaf spring 568. The end of the detent has a wide head 570 with inclined abutment faces 572 resting against similar faces on the latch arm. As a consequence, the latch arm 588 releases the detent 550 when the latch is released and the spiral spring can return the ratchet wheel against a stop as soon as the pawl 538 is raised. The pawl is released by a depending lug 574 on the head of the valve stem which is forced out by a coil spring 576 in a valve cylinder 578. The head of the valve abuts against the plunger 580 of a solenoid 582 which is energized to restore the valve to latched position and to restore the timing ratchet mechanism to operative position. The movement of the plunger 580 operates a bent lever 584 which is pressed against the head of the plunger by a coil spring 586, thereby opening or closing switch contacts at 588. The function of this switch is to control the stopping of the oscillation of the work head as will appear. The valve cylinder 578 has two connected ports 590 for exhaust of fluid and also has a central inlet port 592 for admitting pressure fluid. In the position illustrated, pressure fluid is directed between the two right hand pistons to a passage 594 leading to a series of cylinders and exhaust fluid comes back through a passage 596 to the space between the two left hand pistons. When the valve is slid to the left, the course of fluid is reversed in the system as will later appear more in detail.

Reversal of feed screw and resetting of feed ratchet.—See Figs. 25, 26, 27 and 28. Although the jump-back cylinder 416 of course retracts the wheel from the work, it is also desirable to reverse the feed screw and ratchet wheel to make ready for a new feed by the pawls. The feed screw extends rearwardly through a sleeve 600 which is integral with an oscillating vane 602 in a sector shaped cylinder 604 having the fluid supply pipes 606 and 608. The cylinder has heads 610 and 612 provided with packing glands 614 for the sleeve 600, and one of the heads 610 has lugs 615 fastened to the rear side of the main slide 22. The extended end of the sleeve is keyed to a collar 616 having a fork 618 receiving a lever 620 pivoted at 622 to the arms of the fork. A leaf spring 624 tends to press a tooth 626 at one end of the lever into engagement with the teeth of a ratchet wheel 628 fixed on the rear end of the feed screw by a nut. The other end of the lever has its sides bevelled as indicated at 630 and is initially held up by a rounded screw 632 on a bracket 634. The vane and its sleeve are turned at the end of the grinding operation by fluid pressure, the collar 616 and the lever 620 turning with the sleeve. When the lever 620 rides off the end of the screw 632, the tooth 626 engages the ratchet wheel and the feed screw is reversed.

The lever is disengaged at any desired point in the oscillating movement by a rib 636 carried on an arcuate plate 638 which is slotted at 640 and fastened in adjusted position to the cylinder head 612 by screws 642. The bevelled sides 630 of the lever act as cams when they engage either the rib 636 or the screw 632. As shown in Fig. 26, the arcuate plate is adjusted so that the feed screw will be reversed through a small angle but the reduction gearing at the front of the feed shaft will cause an increased angular movement of the feed ratchet wheel. The amount of reverse movement can be increased by shifting the arcuate plate and its rib away from the screw 632.

Minor jump back of wheel head.—See Figs. 13A, 13B, 13C and 13D. When, instead of grinding a cone with an arcuate surface R meeting a tangent surface T, as indicated in Figs. 5 and 13A, it is desired to grind a cone with an arcuate surface R connected by a snap rib or hook H to a straight tapering surface S, a minor jump back of the wheel head is employed. This retracts the wheel a slight distance from the deepest part of the arcuate surface R just prior to the run-out of the main slide 22. This action can be employed by threading the rear end of the piston rod 420 in a nut 643 which is rotatably mounted in the lug 428 of the slide plate 430. The nut is connected to a vane 644 in a small sector-shaped cylinder 645 while the rod 420 is splined to the cylinder head 646. Pressure fluid is admitted to one side of the vane just prior to the run-out of the wheel with the main slide so that the surface S, instead of being tangent to the arcuate surface R, is parallel to such a tangent. A snap rib or hook H is thus obtained which will hold the balls of the bearing in their raceway when the other parts of the bearing are assembled as is well understood in the bearing art. The amount of this minor retraction of the wheel will usually be very small and can be regulated or eliminated by adjustable stop screws 647 which limit or prevent the movement of the vane. As will appear in the diagram, the action of the vane can be controlled by a suitable spring-closed check valve 648 so that pressure fluid will go to the vane before opening the valve and continuing on to operate the main slide. When the main slide returns, the vane is reversed.

Main slide.—See Figs. 2, 4 and 31. The main slide 22 slides on ways on the main frame and is actuated by a piston 650 in a cylinder 652. When pressure fluid is admitted through a pipe 654 and passages 656 to one end of the cylinder, exhaust fluid from the other end of the cylinder goes through a passage 658 to a pipe 660. A piston rod 662 is adjustably connected to a bracket 664 on the main slide 22 and movement of the slide in one direction is limited by a stop screw 666. The main slide has a casing 668 of insulating material adjustably supporting a series of insulating blocks or dogs 670. One dog opens and closes switch contacts at 672, another closes and opens switch contacts at 674; a third opens and closes switch contacts at 676 and a fourth opens and closes switch contacts at 678. The purpose of these will appear later.

Loading mechanism.—See Figs. 29 and 30. A loader for presenting work-pieces to the chuck is carried by the main slide and a part of the loader projects over and clears the cross slide 18. A cylinder 700 has piston 702 with a piston rod 704 to the end of which a bent arm 706 is secured by a screw 708. A work carrier 710 is re-

movably secured to the arm 706 and is open at the end and at the top, as at 712, to receive a work-piece W from the magazine 26. The magazine is secured in vertically adjusted position on a bracket 713 by bolts 714 and the bracket is adjustable lengthwise of the cylinder by bolts 716. Leaf springs 718 in slots of the carrier hold the work-piece at its bottom and sides. The carrier has a top wall or guard 720 with a cam at one end to raise and hold back the remaining work-pieces in the magazine when the loader advances. In the carrier back of the work-piece is a cupped member 722 which is held forward by a coil spring 724, the member 722 having a guide rod 726 threaded at the end to receive a stop nut 728 for limiting forward movement. Fluid pressure enters the cylinder at 730 to advance the loader while exhaust fluid goes out at 732. The loader carries the work-piece to the chuck and, as soon as the chuck stops the piece, the coil spring 724 yields but holds the piece while the chuck grips it. The ends of the leaf springs 718 are rounded so that they are cammed outwardly by contact with the chuck and will ride back outside the held piece when the loader is retracted. The piston rod 704 is extended into a casing 736 and carries a block of insulation 738 supporting a contact spring 740. The spring is arranged to engage a pair of switch contacts at 582A on an insulating cover 744 or to engage a pair of switch contacts at 224A on an insulating cover 748. The switch contacts control the before mentioned solenoids 582 and 224, respectively, as will appear. The loader base has longitudinal slots 750 for T-headed bolts 752 whose heads 756 are adjustable laterally in cross slots 758 in a supporting plate 760. The supporting plate 760 is secured to the main slide 22 by bolts 762 in cross slots. The bolt and slot connections permit the loader to be adjusted at the same angle as the work head so as to line up with the chuck.

Fluid pressure and wiring diagram.—See Fig. 32. Pressure fluid from a pump passes through a piston shut-off valve 822 which is normally held open by a solenoid 824 under control of a switch 826. The pressure fluid is conducted by branch piping to a series of control valves, and exhaust branches of the piping return the spent fluid. The letter P indicates those branches in which fluid is always under pressure and the letter E indicates those branches in which the fluid is always free to return to the exhaust line. In other pipes, the fluid is alternately under pressure and free to exhaust.

A main reversing valve 832 controls the oscillation of the work head. The details of this valve need not be gone into but it will suffice to say it comprises a sliding piston valve 834, an operating piston 836 therefor, and a hollow control valve 838 having an operating rod 840. The rod 840 reciprocates under control of solenoids A and B which are alternately energized under control of switches C and D actuated by the dogs 350 on the oscillated shaft 272. Pressure fluid from the reversing valve 832 alternately passes through pipes 842 and 844 and through an interposed shut-off valve 846 to passages in the upper and lower heads of the cylinder 314 containing the two vanes 326. The dogs 350 close the switches C and D alternately and thereby energize the solenoids A and B to reverse the flow of fluid and change the direction of swing of the work-head. The solenoids are connected to branches of a

power line having a switch 858. During the oscillation of the head, the third dog 352 repeatedly throws the switch 356 but the switch is not effective to operate its solenoid 356B until another switch 356A is closed as will appear.

During grinding and with the wheel receiving a coarse feed by the pawls, the feeler gauge follows the diminishing work, its contact control arm 860 swinging to the left and, near the end of the grinding operation, brings the contacts together at 862. A circuit is thus completed from low voltage line wires 864 and 866 through a relay magnet 868 to close a relay switch 870. Magnet 510 is thereupon energized to swing the lever 506 and reduce the cross feed by restricting the movement of both feed pawls. When the work is down to final size, the contact control arm 860 separates a pair of contacts at 876 and thereby breaks a circuit which was holding energized a relay magnet 878. The relay switch thereupon brings together contacts at 880 to energize the magnet 512 which thereupon stops the feed by retracting the feed pawls. The separation of the gauge contacts at 876 also breaks a branch circuit from the line wires to a relay magnet 884, thereby bringing two contacts together at 356A and rendering the contacts at 356 alive ready to repeatedly energize the solenoid 356B as the work-head continues to oscillate after cross feed ceases. The number of spark-out strokes is controlled by the timing ratchet wheel 540 which trips the latch 560 to release the main control valve stem 564 and so reverse the flow of fluid in the piping. The stem slides to the left under pressure of its spring 576 and opens the switch contacts at 588. This de-energizes a solenoid 588A and allows a coil spring 892 to close the shut off piston valve 846 and stop oscillation of the work head.

Other things occur when the valve stem 564 is advanced by its spring. Pressure fluid is directed between the two right hand pistons through a pipe 894 and its branch pipe 256 to the left end of the locking piston 240, exhaust fluid leaving the right side of such piston through the branch 258 of a pipe 898 and going around the coil spring 576 to the permanent exhaust line E. The locking piston 240 advances the lock slowly (by reason of the throttled passage 266) to accurately locate and lock the work head in position for further operations on the work. As the lock advances, it closes the switch contacts at 252 and a circuit is completed through branches of the main power line to energize a solenoid 252A and slide a valve stem 900 to the left in a cylinder 901. The fluid can exhaust from the left of the valve cylinder through a passage 902 and through a branch 898A of pipe 898 which is then an exhaust line. Pressure fluid enters the valve cylinder 901 through the pipe 894, first going around another valve stem 904 and through a passage 906 to the space between the two middle pistons on the stem 900. The fluid is then directed into the pipe 654, first operating the vanes in sector cylinder 645, optionally, for minor wheel retraction, then opening check valve 648 and going to the main slide operating cylinder 652. The piston 650 in this cylinder is moved to the right during which time the straight part of the race ring is ground. Exhaust fluid from the main slide cylinder 652 passes out into the pipe 660 which is a branch of pipe 898.

As the main slide starts out, it separates switch contacts at 672 and releases a vertical valve stem

914 by de-energizing a connected solenoid 672A which previously was held energized by branches of the main power line. The valve stem 914 descends by gravity blocking its cylinder 915 off from a branch 898B of pipe 898 and putting a pipe 916 in communication with the permanent exhaust line E. As the main slide completes its outward movement, it closes switch contacts at 674 and energizes solenoids 674A and 674B.

10 When solenoid 674B is energized, it moves a valve stem 918 to the left in its cylinder 919 and places the permanent pressure line P in communication with a pipe 920 leading to the rear of the jump back cylinder 416 and so retracting the wheel head. Exhaust fluid from the jump back cylinder returns through pipe 924 to the right of both valve pistons and so enters the permanent exhaust line E.

20 Solenoid 674A also being energized, the valve stem 904 which has four pistons is moved to the left. Pressure fluid from pipe 894 is now directed between the two middle pistons and through a pipe 926 to the feed screw retractor vane 602 and to the gauge moving cylinder, thus reversing the feed screw and lifting the gauge stem bodily. Pressure fluid in pipe 926 opens a check valve 928 against the pressure of a coil spring 930 and continues through the pipe 226 to the control valve cylinder 218 of the chuck and ejector. The fluid passes between the two pistons of the control valve and through the pipe 214 to advance the ejector piston 188; the fluid also continues on through the passage 182 to advance the chuck piston 166. The finished workpiece is thus released and ejected. The space at the right of the two pistons 166 and 188 is in communication through the pipes 216 and 228 with the permanent exhaust line E and the coil springs are compressed.

40 While the chuck piston 166 is advancing, its stem closes switch contacts at 178 and energizes a solenoid 178A which is thus placed in circuit with branches of the main power line. The solenoid 178A pulls out on a valve stem 944 of a cylinder 946 and puts a branch of the pressure line P into communication with two other cylinders. A pipe 948 conducts the pressure fluid to the loading cylinder 700 at the right of its piston to advance the loader with a new work-piece. Exhaust fluid goes back through a pipe 950 and past the end piston on the stem 944 to the permanent exhaust line E. At the beginning of its advance stroke, the loader piston rod 704 separates switch contacts at 582A these being already dead however because of the separation of contacts at 582B controlled by a contact operating piston 952. This last piston advances when the loader advances but a throttle valve 954 retards it so that an insulating plate 955 on its piston rod does not make the contact at 582B until the loader has separated the contacts at 582A. Hence switch contacts at 582A do not become effective until the loader is subsequently retracted to again close the contacts at 582A. At the end of its advance stroke to the left, the loader closes the switch contacts at 224A and energizes the solenoid 224 thereby moving the chuck valve piston inwardly to the right. This blocks off fluid pressure at the pipe 226 from access to the chuck cylinder and ejector cylinder but places passage 182 and pipe 214 in communication with the pipe 228 leading to the permanent exhaust line E. Coil springs back of the pistons 166 and 188 will then shift the pistons to the left whereby the chuck grips the new work piece and

the ejector is reset. (The solenoid can thus move the valve to the right without opposition from fluid pressure because the passage 232 connects the right hand end of the cylinder 218 with the corresponding end of the locking cylinder then exhausting to pipe 258.)

As the chuck piston 166 thus returns to the left by spring pressure, the contacts at 178 are opened and solenoid 178A is de-energized. A coil spring 956 thereupon shifts the valve stem 944 inwardly. Pressure fluid then passes from the pressure line P through pipe 950 to return the loader to the right to its retracted position. Exhaust from the loader cylinder is through pipe 948, past the piston 952, and through coil spring 956 to the permanent exhaust line E. As the loader retreats, it opens switch contacts at 224A, de-energizing solenoid 224 and then closes switch contacts at 582A to energize solenoid 582. (The contacts at 582B are still held closed by piston 952 because both sides of the piston are then open to an exhaust line and in practice the stem of piston 952 is horizontal so that gravity does not tend to retract it). Solenoid 582 restores the stem 564 of the main control valve to latched position and thus immediately puts the pressure line P in communication with the pipe 898 and its branches, while pipe 894 and its branches have access to exhaust line E. Pressure fluid entering pipe 258 quickly retracts the locking piston 240 (opening switch contacts at 252) and pressure fluid in passage 232 retracts the chuck control valve, the port 230 at the left end of the cylinder being always open to pipe 228 and exhaust line E. Pressure fluid in branch pipe 898A forces back both valve stems 900 and 904 and also goes through branch pipe 660 to the main slide cylinder 650 to advance the main slide. Pressure fluid also goes through a branch pipe 661 to the cylinder 645 to restore the vane 644 and nut 643. Exhaust from cylinder 645 is through pipe 654 and a branch 654A to the space between the two right hand pistons on the stem 900 and then to the permanent exhaust line E. Exhaust from the main cylinder 652 is through the closed check valve 648 to a permanent exhaust line E. When solenoid 582 is energized to restore the main control valve stem 564, switch contacts at 588 are closed thereby energizing solenoid 588A to open the shut off valve 846 and start oscillation.

As the main slide advances, switch 674 is opened and solenoids 674A and 674B are de-energized. (Pressure fluid in pipe 898A can operate stem 904 even if solenoid 674A is energized.) A coil spring 958 then restores valve stem 918 to the right. Pressure fluid in the pressure line P is then directed through the pipe 924 to the jump back cylinder 416 to advance the wheel head. Exhaust fluid in pipe 920 goes through the coil spring 958 to the permanent exhaust line E. Meanwhile the feed screw retractor and gauge are held inoperative because the pistons of valve stem 914 of solenoid 672A are still depressed to obstruct the adjacent branch 898B of pipe 898 from access to pipe 916. As the main slide completes its advance to the left, it closes switch contacts at 672 and energizes solenoid 672A to raise the valve stem 914. Thereupon the pressure fluid in pipe 898B is placed in communication with pipe 916 and its branch 916A. The piston 952 is thus actuated to separate the switch contacts at 582B. The pressure fluid in the pipe 606 which is a branch of pipe 916 also resets the feed screw retractor vane to 75

hasten the feed and fluid in a branch 916C lowers the gauge stem to the work, the movement of the gauge stem being slow by reason of the throttling action in the passage 138. Exhaust from the gauge cylinder and from the vane occurs through the branches of pipe 926. Check valve 928 closes by pressure of its coil spring 930 as soon as pipe 926 and its branch 926A are connected to the exhaust line E by the restoration of valve stem 904. The motor 45 in the work head is shut off when the main slide 22 retreats and starts when the main slide advances. The switch contacts at 676 and 678 are closed by the dogs on the main slide 22 when the main slide advances and a circuit is completed through a relay 972 to close a relay switch 974. Current from the line wires 976 then starts the motor. When the slide retreats, the switch contacts at 676 and 678 are separated and the relay switch 974 is opened to stop the motor. A push button switch 978 can also be used to control the relay to start or stop the motor.

I claim:

1. In a machine of the character described, a work head, a tool head, feed mechanism, means for operating the feed mechanism in one direction to produce a relative feeding movement of approach between the heads, mechanism independent of the feed mechanism and comprising a cylinder and piston unit directly connected to one of the heads for separating the heads in the line of feed, and mechanism for operating the feed mechanism in the opposite direction; substantially as described.

2. In a machine of the character described, a work head, a tool head, a feed screw, mechanism for turning the feed screw in one direction to effect a relative feeding movement of approach between the heads, mechanism independent of the feed screw and directly connected to one of the heads for separating the heads in the line of feed, and mechanism for turning the feed screw in the opposite direction; substantially as described.

3. In a machine of the character described, a work head, a tool head, a feed screw, pawl and ratchet mechanism for turning the feed screw in one direction to effect a relative feeding movement of approach between the heads, mechanism independent of the feed screw for shifting one of the heads with respect to the screw and so separating the heads in the line of feed, and fluid pressure mechanism for turning the feed screw in the opposite direction; substantially as described.

4. In a machine of the character described, a work head, a tool head, mechanism for effecting a feeding movement of approach between the heads, mechanism for effecting a minor movement of separation between the heads, and mechanism for effecting a major movement of separation between the heads, said last two mechanisms comprising a piston having a piston rod with a threaded portion, and a rockable nut on the threaded portion; substantially as described.

5. In a machine of the character described, a work head, a tool head, a feed screw, mechanism for turning the feed screw to effect a relative feeding movement of approach between the heads, mechanism for effecting a minor separation of the heads in the line of feed, mechanism for causing a relative shifting movement of the heads in another direction for a machining operation, and automatic mechanism for thereafter

effecting a major separation of the heads in the line of feed; substantially as described.

6. In a machine of the character described, a work head, a tool head, a feed screw, mechanism for turning the feed screw to effect a relative feeding movement of approach between the heads, mechanism for effecting a minor separation of the heads in the line of feed, mechanism for effecting a major separation of the heads, and mechanism for reversing the feed screw; substantially as described.

7. In a machine of the character described, a work head, a tool head, a cylinder and vane for effecting a minor movement of separation between the heads, a jump-back cylinder and piston unit for effecting a major movement of separation between the heads, and means for causing a relative shifting of the heads to occur in a longitudinal direction between the operation of the two separating mechanisms; substantially as described.

8. In a machine of the character described, a work head, a tool head, means for causing relative movement of the heads and comprising a piston, a piston rod and a cylinder, a portion of the piston rod being threaded, a nut threaded on the piston rod, and means for turning the nut for causing a subsidiary relative movement of the heads; substantially as described.

9. In a machine of the character described, a head, a plate having sliding engagement with the head, means for causing relative movement between the head and the plate and comprising a piston, a piston rod, and a cylinder, the piston rod being threaded, a nut threaded on the piston rod and supported by the plate, and means for causing relative rotation between the nut and the rod for effecting a subsidiary relative movement of the head and the plate; substantially as described.

10. In a machine of the character described, a work head, a tool head, a feed screw, mechanism at one end of the feed screw for turning the feed screw in one direction to effect a relative feeding movement of approach between the heads, mechanism at the other end of the feed screw for turning the screw in the opposite direction, the intermediate portion of the feed screw having threaded connection with one of the heads; substantially as described.

11. In a machine of the character described, a work head, a tool head, a feed nut, a feed screw, means for turning the screw in one direction to effect a relative movement between the heads, a cylinder, and a vane in the cylinder and having a one way connection with the feed screw for turning the screw in the opposite direction; substantially as described.

12. In a machine of the character described, a work head, a tool head, a feed screw, a cylinder, a vane rockable on the feed screw, and means for clutching the vane to the feed screw; substantially as described.

13. In a machine of the character described, a work head, a tool head, a feed screw, a cylinder, a vane rockable on the feed screw, and means for clutching the vane to the feed screw and comprising a ratchet wheel carried by one of said last members, and a movable dog connected to the other; substantially as described.

14. In a machine of the character described, a work head, a tool head, a feed screw, a cylinder, a vane, and means for clutching the vane to the feed screw and comprising a ratchet wheel car-

ried by one of said last members and a movable dog connected to the other, and a cam for controlling the dog; substantially as described.

15. In a machine of the character described, a work head, a tool head, a feed screw, a cylinder, a fluid pressure operated member projecting from the cylinder, said member forming a journal support for the feed screw, and means for clutching the member to the feed screw; substantially as described.

16. In a machine of the character described, a work head, a tool head, a feed screw, a cylinder, a fluid pressure operated member projecting from the cylinder, and a pivoted dog carried by said member for connecting the member to the feed screw; substantially as described.

17. In a machine of the character described, a work head, a tool head, a feed screw, a cylinder, a fluid pressure operated member projecting from the cylinder, a pivoted dog carried by said member, a ratchet wheel carried by the feed screw, and a cam for swinging the dog; substantially as described.

18. In a machine of the character described, a work head, a tool head, a feed screw for effecting a relative feeding movement of approach between the heads, a cylinder and vane for effecting a minor movement of separation between the heads, and a cylinder and vane for effecting a reversal of the feed screw; substantially as described.

19. In a machine of the character described, a work head, a tool head, a cylinder and piston unit for causing a movement of separation between the heads, a screw shaft, a nut threaded on the shaft, means connecting the nut to one member of the cylinder and piston unit, and a cylinder and vane for causing a relative turning of the shaft and the nut to increase the movement of separation; substantially as described.

20. In a machine of the character described, a work head, a tool head, a cylinder, a vane turning in the cylinder, a shaft connected to one of the heads and having a threaded connection with the vane for effecting a movement of separation between the heads, a screw shaft, and a cylinder and vane for turning the screw shaft to effect another relative movement of the heads; substantially as described.

21. In a machine of the character described, a work head, a tool head, a feed screw for effecting a relative feeding movement of approach between the heads, mechanism for effecting a minor movement of separation of the heads to separate the tool from a completed portion of the work and place it in machining relation to another portion of the work, automatic mechanism for causing a relative shifting of the heads to effect a further machining operation after said minor movement of separation, and mechanism for effecting a reversal of the feed screw; substantially as described.

22. In a machine of the character described, a work head, a tool head, mechanism for causing a minor movement of separation between the heads, mechanism for causing a major movement of separation between the heads, a screw shaft, and mechanism for turning the screw shaft to further effect separating movement of the heads; substantially as described.

23. In a machine of the character described, a work head, a tool head, a cylinder and piston unit for causing a major movement of separation between the heads, a cylinder and vane for caus-

ing a minor movement of separation between the heads, and a cylinder and vane for effecting a further relative movement of the heads; substantially as described.

24. In a machine of the character described, a work head, a tool head, mechanism for causing a relative feeding movement of approach between the heads, mechanism for reciprocating one of said heads to machine one portion of the work, mechanism for causing a minor movement of separation between said heads in the line of feed to place the work and the tool in a different machining relation and mechanism for thereafter moving one of said heads substantially transversely to the line of feed for a further machining operation upon another portion of the work; substantially as described.

25. In a machine of the character described, a work head, a tool head, mechanism for causing a relative feeding movement of approach between the heads, mechanism for oscillating one of said heads in a curved path for production of a curved surface on the work, mechanism for causing a movement of separation between the heads in the line of feed, and mechanism for moving one of said heads substantially transversely to the line of feed to produce a straight surface meeting the curved surface; substantially as described.

26. In a machine of the character described, a work head, a tool head, mechanism for causing a relative feeding movement of approach between the heads, mechanism for oscillating one of said heads in a curved path for production of a curved surface on the work, mechanism for stopping the relative feeding movement and thereafter continuing the oscillation for a predetermined number of strokes, and mechanism operable after the termination of oscillation for moving one of said heads substantially transversely to the line of feed to produce a straight surface on the work; substantially as described.

27. In a machine of the character described, a work head, a tool head, mechanism for causing a relative feeding movement of approach between the heads, mechanism for oscillating one of said heads in a curved path for production of a curved surface on the work, mechanism for stopping the relative feeding movement and for stopping the oscillation, and mechanism for moving one of said heads substantially transversely to the line of feed to produce a straight surface on the work; substantially as described.

28. In a machine of the character described, a work head, a tool head, mechanism for moving one of the heads in a curved path with respect to the other head, with the work and tool in contact, automatic mechanism to stop said movement with the work and tool in contact, and automatic mechanism for thereafter giving a run-out cutting stroke to one of the heads in a straight path with respect to the other with the work and tool in contact; substantially as described.

29. In a machine of the character described, a work head, a tool head, mechanism for moving one of the heads in a curved path with respect to the other head, with the work and tool in contact, mechanism to stop said movement with the work and tool in contact, automatic mechanism for thereafter giving a single run-out cutting stroke to one of the heads in a straight path with the work and tool in contact, and automatic mechanism to separate said work and tool in a direction transversely of the run-out cutting stroke; substantially as described.

30. In a machine of the character described, a

head, mechanism for feeding the head comprising a pair of feed members, a plunger for actuating each of the feed members, an arm engaging one of the plungers, a lever engaging the other plunger, and means for causing the arm and the lever to actuate the plungers alternately; substantially as described.

31. In a machine of the character described, a head, mechanism for feeding the head comprising a pair of feed members, a plunger for actuating each of the feed members, an arm engaging one of the plungers, a lever engaging the other plunger, means for causing the arm and the lever to actuate the plungers alternately, and means for restricting the movement of the feed members; substantially as described.

32. In a machine of the character described, a head, a ratchet wheel for advancing the head, a pair of pawls, a lever carrying each pawl, a plunger engaging each lever, an oscillating arm engaging one of said plungers, a lever engaging the other plunger, and means for connecting the last said lever to the arm whereby one of the plungers is actuated by a swing of the arm in either direction; substantially as described.

33. In a machine of the character described, a head, a ratchet wheel for advancing the head, a pair of pawls, a lever carrying each pawl, a plunger engaging each lever, an oscillating arm engaging one of said plungers, a lever engaging the other plunger, means for connecting the last said lever to the arm whereby one of the plungers is actuated by a swing of the arm in either direction, and a stop movable into the path of the pawl carrying levers to shorten the stroke thereof; substantially as described.

34. In a machine of the character described, a head, a ratchet wheel for advancing the head, a pair of pawls, a lever carrying each pawl, a plunger engaging each lever, an oscillating arm engaging one of said plungers, a lever engaging the other plunger, means for connecting the last said lever to the arm whereby one of the plungers is actuated by a swing of the arm in either direction, a stop movable into the path of the pawl carrying levers to shorten the stroke thereof, and a member for moving the pawls away from the ratchet wheel; substantially as described.

35. In a machine of the character described, a head, a ratchet wheel for advancing the head, a pair of pawls, a sliding plunger for advancing each pawl in one direction, means for retracting the pawls, an arm engaging one of said plungers, a lever engaging the other plunger, and means for causing the arm and the lever to actuate the plungers alternately; substantially as described.

36. In a machine of the character described, a work head, a tool head, mechanism for feeding one of the heads comprising a pair of movable members, means for alternately giving the feed members a feed stroke, and a work gauge controlling a shortening of the stroke of the feed members; substantially as described.

37. In a loading mechanism, a work holder, a carrier for a work-piece, a spring pressed plunger movably mounted on the carrier, means for limiting the movement of the plunger towards the work-piece, and means for advancing the carrier towards the work holder to bring the plunger and the work-piece in contact; substantially as described.

38. In a loading mechanism, a work holder, a carrier for a work-piece, springs holding the work-piece on the carrier, means for advancing the carrier towards the work holder, and the work

holder having spring engaging means to release the holding springs; substantially as described.

39. In a loading mechanism, a work holder, a carrier for a work-piece, springs holding the work-piece on the carrier, a yieldable plunger movably mounted on the carrier, and means for advancing the carrier towards the work holder; substantially as described.

40. In a loading mechanism, a work holder, a carrier receiving a work-piece, a piston and cylinder unit for bodily advancing the carrier towards the work holder, and means operable on the advance of the carrier for yieldably presenting the work-piece to the work holder; substantially as described.

41. In a loading mechanism, a work holder, a carrier receiving a work-piece and having work holding springs projecting beyond the work towards the work holder, means for advancing the carrier towards the work holder, and the work holder having means for gripping the work-piece and another means to engage the projecting springs for releasing the piece from the carrier; substantially as described.

42. In a loading mechanism, a work holder, a carrier receiving a work-piece, means for advancing the carrier towards the work holder, the work holder having work gripping means, and means controlled by the advance of the carrier for initiating the operation of the work gripping means; substantially as described.

43. In a machine of the character described, a work holder having work gripping means, mechanism for releasing the gripping means from a work-piece, a loading mechanism, and means controlled by the releasing mechanism for initiating the operation of the loading mechanism; substantially as described.

44. In a machine of the character described, a work holder having work gripping means and a work ejector, mechanism for releasing the gripping means from a work-piece and operating the ejector, a loader for the work holder, and means controlled by the said mechanism for initiating the operation of the loader; substantially as described.

45. In a machine of the character described, a work holder having a work ejector, mechanism for controlling operation of the ejector, a loading mechanism, and means operated by the ejector controlling mechanism for initiating the operation of the loading mechanism; substantially as described.

46. In a machine of the character described, a work holder having a work ejector, mechanism for controlling advance of the ejector, a loading mechanism, means operated by the ejector controlling mechanism for initiating the operation of the loading mechanism, and mechanism for retracting the ejector; substantially as described.

47. In a machine of the character described, a work holder having work gripping means and a work ejector, mechanism for releasing the gripping means from a work-piece and operating the ejector, a loader for the work holder, means controlled by the said mechanism for initiating the operation of the loader, and mechanism controlled by the loader for initiating a gripping operation of the work holder; substantially as described.

48. In a machine of the character described, a work holder having work gripping means and a work ejector, a cylinder and piston unit for controlling the operation of the work gripping means, and a cylinder and piston unit for controlling the

operation of the ejector; substantially as described.

49. In a machine of the character described, a work holder having a work engaging member, a movable plunger, a trip dog carried by the plunger for moving the member in one direction, means for tripping the dog, and a spring for moving the member in the opposite direction; substantially as described.

50. In a machine of the character described, a work holder having a work engaging member, a spring for moving the member in one direction, a plunger, a dog pivoted to the plunger, and an arm in the path of the dog and connected to the member; substantially as described.

51. In a machine of the character described, a work holder having a work engaging member, an arm connected to the member, a plunger, a dog pivoted to the plunger and engageable with the arm, and means in the path of the dog for disengaging the dog from the arm; substantially as described.

52. In a machine of the character described, a hollow spindle having a chuck with a work locating shoulder, work gripping means on the chuck, a work ejector mounted on the chuck, a sleeve slidably mounted in the spindle, a rod slidably mounted in the sleeve, the sleeve and the rod having connections one with the work gripping means and the other with the ejector, and means for actuating the sleeve and the rod in two directions; substantially as described.

53. In a machine of the character described, a hollow spindle having a chuck with a work locating shoulder, work gripping means on the chuck, means extending through the spindle and connected to the work gripping means, a work ejector, means extending through the spindle and connected to the ejector, springs for actuating said means in one direction, and mechanism acting against the springs to actuate said means in the opposite direction; substantially as described.

54. In an oscillating grinding machine, a work head having a chuck, work engaging means on the chuck, means extending through the work head for operating the work engaging means, a support separate from the work head, and mechanism on said support for controlling said operating means; substantially as described.

55. In a machine of the character described, a head, means for reciprocating the head, means for locking the head, and means associated with the locking means for locating the head in a predetermined position; substantially as described.

56. In a machine of the character described, a head, a support, cooperating means carried by the head and the support and comprising a plunger and a notch, means for reciprocating the head, and means for advancing the plunger to locate the head in a predetermined position; substantially as described.

57. In a machine of the character described, a head, means for reciprocating the head, a latch plate, a locking plunger, the latch plate and the plunger having cooperating cam surfaces, and means for advancing the plunger to locate and lock the head in a predetermined position; substantially as described.

58. In a machine of the character described, a head, means for reciprocating the head in a curved path, a support, cooperating means carried by the head and the support and comprising a notched plate and a plunger, and means for advancing the plunger to locate the head in a

predetermined angular position; substantially as described.

59. In a machine of the character described, a work head having a chuck with a work engaging member, means for reciprocating the head, a support, means carried by the support for actuating the work engaging member, and means for locking the work head in a predetermined relation to the actuating means; substantially as described.

60. In a machine of the character described, a work head having a chuck with a work engaging member, means for oscillating the head in a curved path, a support, means carried by the support for actuating the work engaging member, and means for locking the work head in a predetermined relation to the actuating means; substantially as described.

61. In a machine of the character described, a work head having a work engaging member, a rod for operating the member, a support, rod actuating means on the support, means for reciprocating the work head, and means for stopping the work head with the rod in substantial alignment with the rod actuating means; substantially as described.

62. In a machine of the character described, a work head having a chuck, a work gripping member and an ejector carried by the chuck, means for reciprocating the work head, a support, means carried by the support for actuating the work gripping member and the ejector, and means for locking the work head in operative relation to the actuating means; substantially as described.

63. In a machine of the character described, a work head having a chuck, a support, chuck actuating means carried by the support, and means for adjustably locating the support to place the chuck actuating means in operative relation to the chuck; substantially as described.

64. In a machine of the character described, a work head having a chuck, means for oscillating the head in a curved path, a support, chuck actuating means carried by the support, means for stopping the work head in a predetermined angular position, and means for adjustably locating the support with respect to the stopped position of the work head; substantially as described.

65. In a machine of the character described, a work head having a chuck, means for oscillating the head in a curved path, a support, chuck actuating means carried by the support, a tool head, means for stopping the work head in a predetermined angular relation to the tool head, and means for adjustably locating the support with respect to the work head; substantially as described.

66. In a machine of the character described, a work head having a chuck, means for reciprocating the work head, a loader, means for advancing the loader towards the chuck, and means for locking the work head in a predetermined relation to the loader; substantially as described.

67. In a machine of the character described, a work head having a chuck, means for oscillating the work head in a curved path, a loader, means for advancing the loader towards the chuck, and means for locking the work head in alignment with the loader; substantially as described.

68. In a machine of the character described, a work head, a tool head, means for reciprocating one of the heads, a movable support for the other head, means for locking one of the heads in a predetermined relation to the other head, and means operated by the locking means for initiating a

movement of the movable support; substantially as described.

69. In a machine of the character described, a work head, a tool head, means for oscillating one of the heads in a curved path, a slide for the other head, means for locking the oscillated head in a predetermined angular relation to the other head, and means operated by the locking means for initiating the movement of the slide; substantially as described.

70. In a machine of the character described, a work head having a work engaging member, means for reciprocating the work head, a support, means carried by the support for actuating the work engaging member, a loader, means for advancing the loader towards the work head, and means for locking the work head in operative relation to the loader and the actuating means; substantially as described.

71. In a machine of the character described, a work head having a work engaging member, a support, means carried by the support for actuating the work engaging member, a loader for applying a work-piece to the work head, means for reciprocating the work head, and means for stopping the work head in substantial alignment with the loader and with said actuating means; substantially as described.

72. In an automatic machine of the character described, a work head having a chuck, a tool head, means for reciprocating one of the heads, means for feeding one of the heads towards the other, means for controlling the separation of the heads, means for removing a finished work-piece from the chuck, loading mechanism, means for actuating the loading mechanism to apply a new work-piece to the chuck, and means for causing the actuation of the loading mechanism to initiate an operation on the new work-piece; substantially as described.

73. In an oscillating grinding machine, a work head, a wheel head, means for oscillating one of the heads in a curved path, means for feeding one of the heads towards the other, means for controlling the separation of the heads, means for removing a finished work-piece from the work head, loading mechanism, and means for causing the loading mechanism to apply a new work-piece to the work head and initiate a renewed approach of the heads; substantially as described.

74. In an oscillating grinding machine, a work head, a wheel head, means for oscillating one of the heads in a curved path, means for removing a finished work-piece from the work head, loading mechanism, and means for causing the loading mechanism to apply a new work-piece to the work head and initiate a renewed grinding operation; substantially as described.

75. In an oscillating grinding machine, a work head, a tool head, means for oscillating one of the heads in a curved path, means for locking the oscillated head in a predetermined angular position with respect to the other head, and means for causing a relative movement of the heads in a direction which maintains the heads in said predetermined angular relation; substantially as described.

76. In an oscillating grinding machine, a work head, a tool head, means for oscillating the work head around an axis to procure a curved surface on the work, means for locking the work head in a predetermined angular position with respect to the tool head, and means for causing a run-out cutting stroke of the tool head in a direction which maintains the heads in said predeter-

mined angular relation; substantially as described.

77. In an oscillating grinding machine, a work head, a tool head, means for oscillating the work head around an axis to procure a curved surface on the work, means for locking the work head in a predetermined angular position with respect to the tool head, means for causing a run-out cutting stroke of the tool head in a direction which maintains the heads in said predetermined angular relation, and means for causing a separation of the heads; substantially as described.

78. In a machine of the character described, a work head, a tool head, mechanism comprising a jump-back cylinder and piston unit for causing a movement of separation between the heads, a valve controlling said unit, a slide for one of the heads to provide for a run-out cutting stroke of said head, and mechanism controlled by the slide for initiating the action of the valve; substantially as described.

79. In a machine of the character described, a work head, a tool head, feed mechanism for causing a relative movement of approach between the heads, feed retraction mechanism for causing separation of the heads, a device controlling said retraction mechanism, a movable support for one of the heads, and mechanism controlled by the movable support for initiating the action of said device; substantially as described.

80. In a machine of the character described, a work head, a tool head, a gauge having a work engaging feeler, mechanism for causing a movement of the feeler into operative contact with the work, a movable support for one of the heads, and electromagnetic means controlled by the movable support for initiating the action of said mechanism; substantially as described.

81. In a machine of the character described, a work head, a tool head, means on the work head for gripping or releasing a work-piece, mechanism for actuating said means, a movable support for one of the heads, and means controlled by the movable support for initiating the action of said mechanism; substantially as described.

82. In a machine of the character described, a work head, a tool head, means on the work head for gripping or releasing a work-piece, mechanism for actuating said means, a movable support for one of the heads, means controlled by the movable support for initiating the action of said mechanism, a loader, and means controlled by the releasing means for initiating the operation of the loader; substantially as described.

83. In a machine of the character described, a work head, a tool head, means for oscillating one of the heads, a slide for the other head, a spindle carried by one of the heads, driving means for the spindle, means for stopping the oscillation, and means controlled by the slide for starting and stopping the driving means; substantially as described.

84. In a machine of the character described, a head having a reciprocating support, fluid pressure mechanism for reciprocating the support, a reversing valve controlling the fluid pressure, electromagnetic means for actuating the reversing valve in two directions alternately, and means carried by the reciprocating support for alternately and repeatedly controlling the energization of the electromagnetic means; substantially as described.

85. In a machine of the character described, a head, a reciprocating support for the head, fluid pressure mechanism for reciprocating the sup-

port, a reversing valve controlling the fluid pressure, a shut-off valve for stopping the operation of the fluid pressure mechanism, electromagnetic means and a spring for controlling the operation of the shut-off valve, and means operated by the reciprocating support for making the electromagnetic means ineffective and the spring effective to close the shut-off valve; substantially as described.

86. In an oscillating grinding machine, a head having an oscillating support, fluid pressure mechanism for oscillating the support, a reversing valve controlling the fluid pressure, a shut-off valve for stopping the operation of the fluid pressure mechanism, and means for operating the shut-off valve with the head in a predetermined angular position; substantially as described.

87. In a machine of the character described, a work head, a tool head, means for reciprocating one of the heads, a counting mechanism, electromagnetic means for actuating the counting mechanism, means actuated by the reciprocating head for controlling the electromagnetic means, and means actuated by the counting mechanism for stopping the reciprocation; substantially as described.

88. In a machine of the character described, a work head, a tool head, means for reciprocating one of the heads, means for feeding one of the heads towards the other, a counting mechanism for controlling the stopping of reciprocation, electromagnetic means for actuating the counting mechanism, means actuated by the reciprocating head for controlling the electromagnetic means, and means for stopping the feeding mechanism and starting the counting mechanism; substantially as described.

89. In a machine of the character described, a work head, a tool head, means for reciprocating one of the heads, means for feeding one of the heads towards the other, a counting mechanism for controlling the stopping of reciprocation, a gauge having a feeler engaging a work-piece on the work head, and mechanism for causing the feeler to control the stopping of the feeding mechanism and the starting of the counting mechanism; substantially as described.

90. In an oscillating grinding machine, a work head, a tool head, means for oscillating one of the heads in a curved path, means for feeding one of the heads towards the other, a counting mechanism for controlling the stopping of oscillation, a gauge having a feeler engaging a work-piece on the work head, mechanism for causing the feeler to control the stopping of the feeding mechanism and the starting of the counting mechanism, and means for locking the oscillated head in a predetermined angular relation to the other head; substantially as described.

91. In a machine of the character described, a work head, a tool head, means for reciprocating one of the heads, a counting mechanism for

controlling the stopping of reciprocation, a lock, and lock actuating means controlled by the counting mechanism for securing one of the heads in a predetermined relation to the other; substantially as described.

92. In a machine of the character described, a spindle having a head provided with a plurality of tapering surfaces, means for supporting the spindle for rotation, and wedges movable along said surfaces for expansion in a hollow work-piece; substantially as described.

93. In a grinding machine, a feed pawl, a lever connected to the pawl, means for swinging the lever, a swinging arm having a stop to restrict the lever movement, and means for fixing the stop in selected positions along the arm towards or from its axis to vary the restriction; substantially as described.

94. In a machine of the character described, a hollow spindle having a head provided with a plurality of tapering surfaces, means for rotatably supporting and driving the spindle, wedges shiftable along said tapering surfaces, and means extending through the spindle for actuating the wedges; substantially as described.

95. In an oscillating grinding machine, a head having an oscillating support, fluid pressure mechanism for oscillating the support, a reversing valve controlling said mechanism, a shut-off valve for stopping the operation of the fluid pressure mechanism, electro-magnetic means for controlling operation of the shut-off valve, and means for causing a controlling action of the electro-magnetic means and a stopping of the head in a predetermined angular position.

96. In an oscillating grinding machine, a head having an oscillating support, fluid pressure mechanism for oscillating the support, a reversing valve controlling said mechanism, a shut-off valve for controlling the action of the fluid pressure mechanism, a spring for urging the shut-off valve in one direction, a solenoid connected to the shut-off valve to act in opposition to the spring, and a switch controlling the solenoid.

97. In an oscillating grinding machine, a head having an oscillating support, fluid pressure mechanism for oscillating the support, a reversing valve controlling said mechanism, a shut-off valve for stopping the operation of the fluid pressure mechanism, a spring for urging the shut-off valve in one direction, and electro-magnetic means for controlling a movement of the shut-off valve in opposition to the action of the spring.

98. In an oscillating grinding machine, a head having an oscillating support, fluid pressure mechanism for oscillating the support, a reversing valve controlling said mechanism, a shiftable valve having fluid connections with the reserving valve, a spring for urging the shiftable valve in one direction, and a solenoid connected to the valve to control the shifting movement thereof.

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