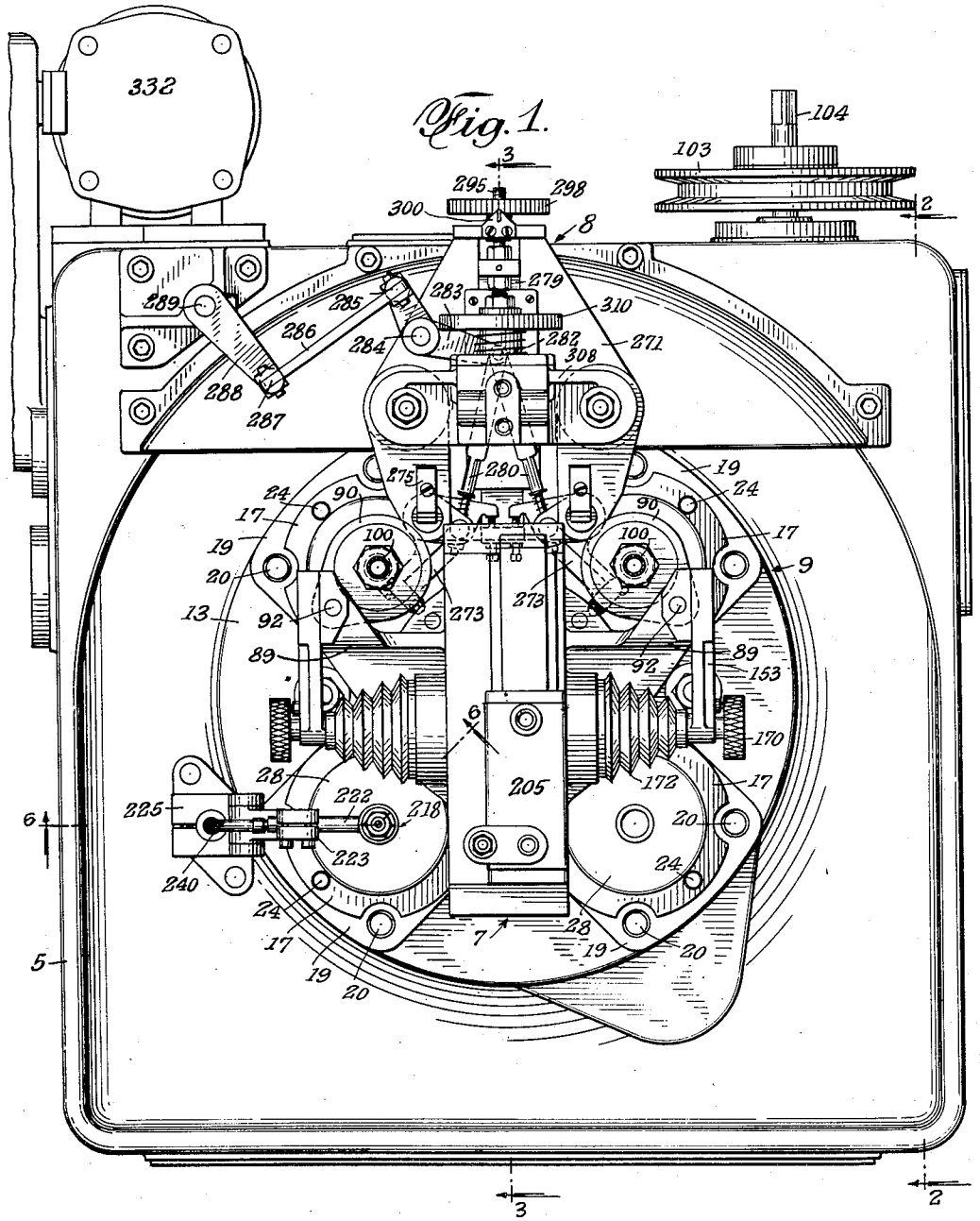
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GRINDER

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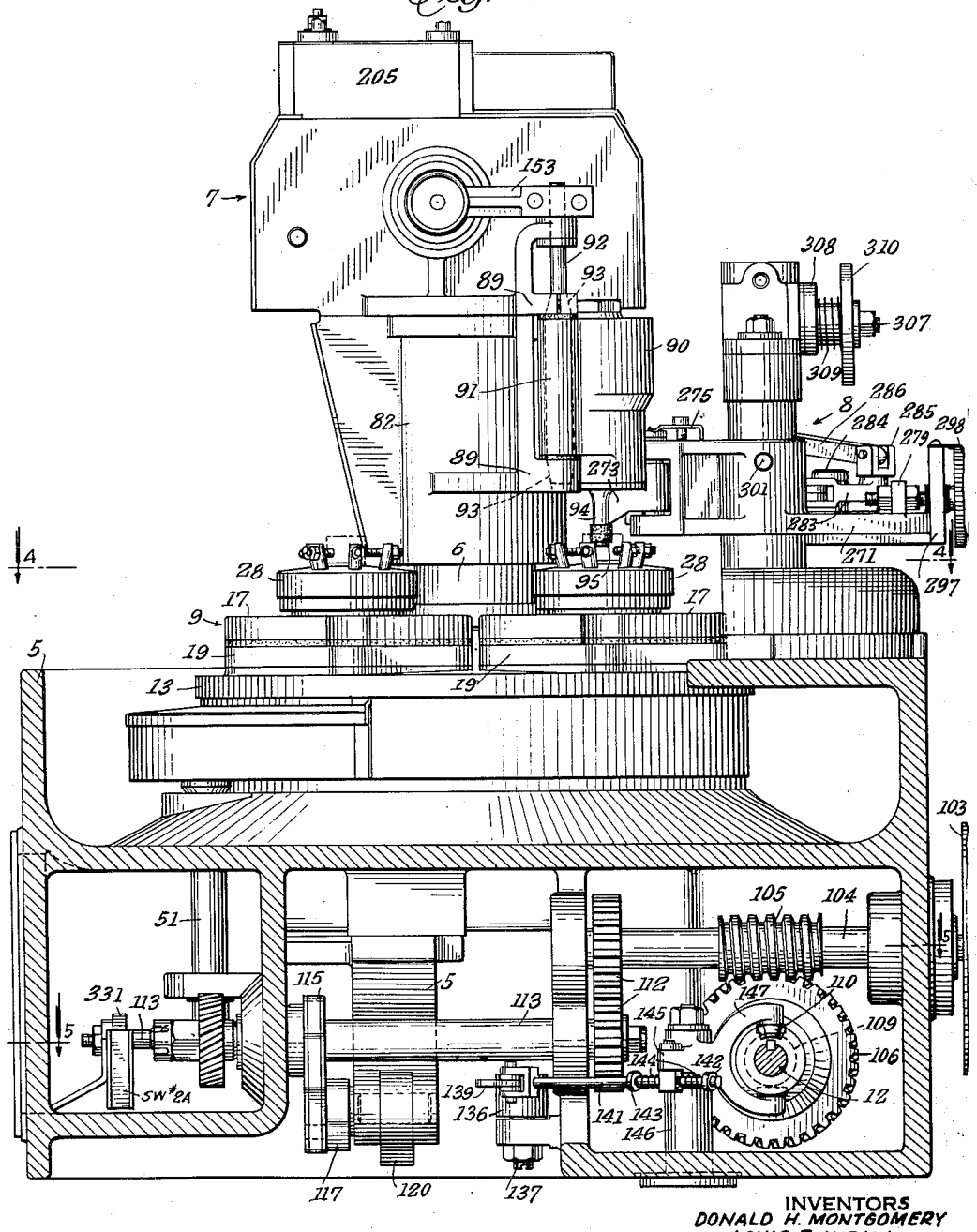
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GRINDER

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Fig. 2.



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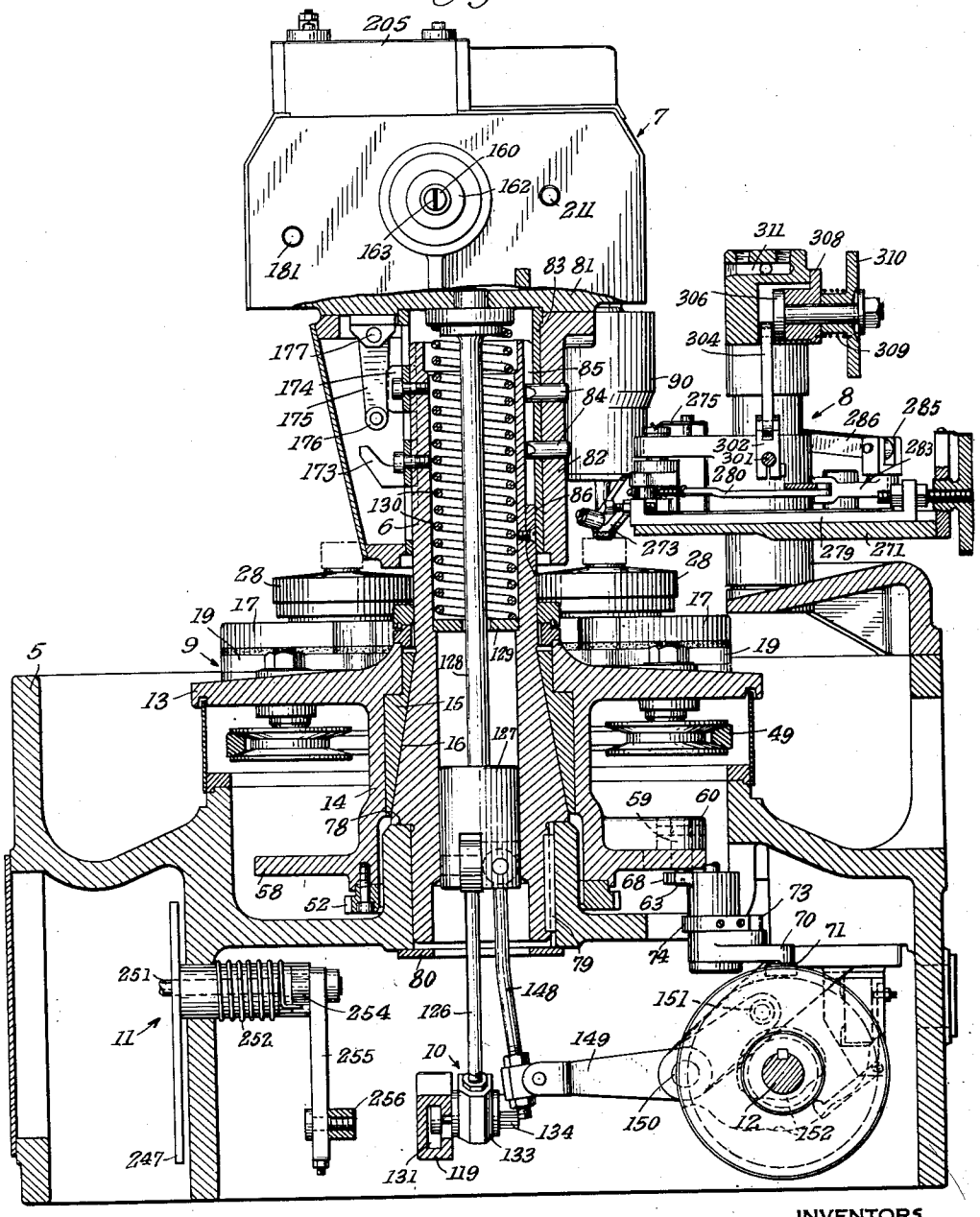
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GRINDER

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Fig. 3.



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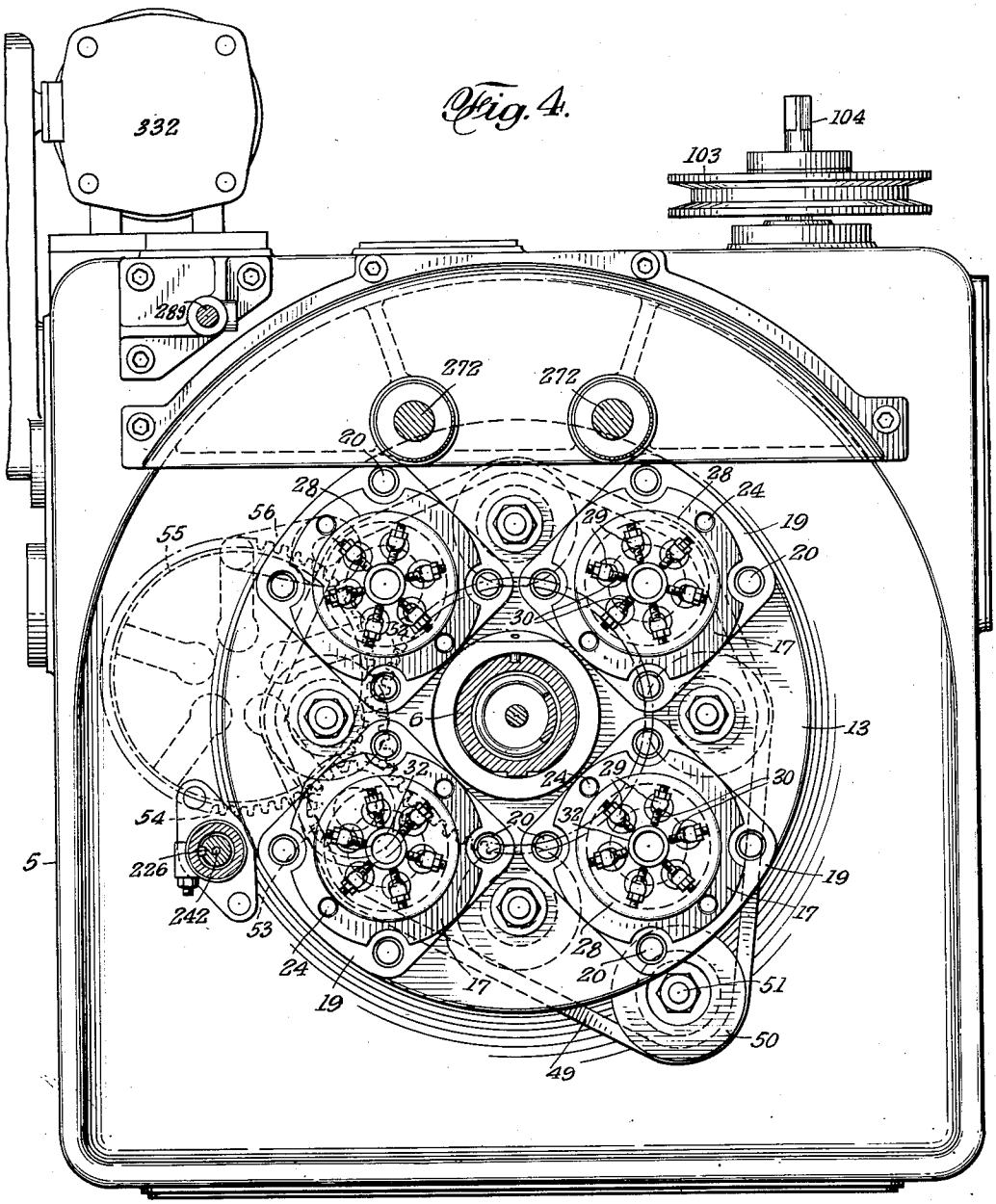
BY Mitchell Burkert
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GRINDER

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Fig. 4.



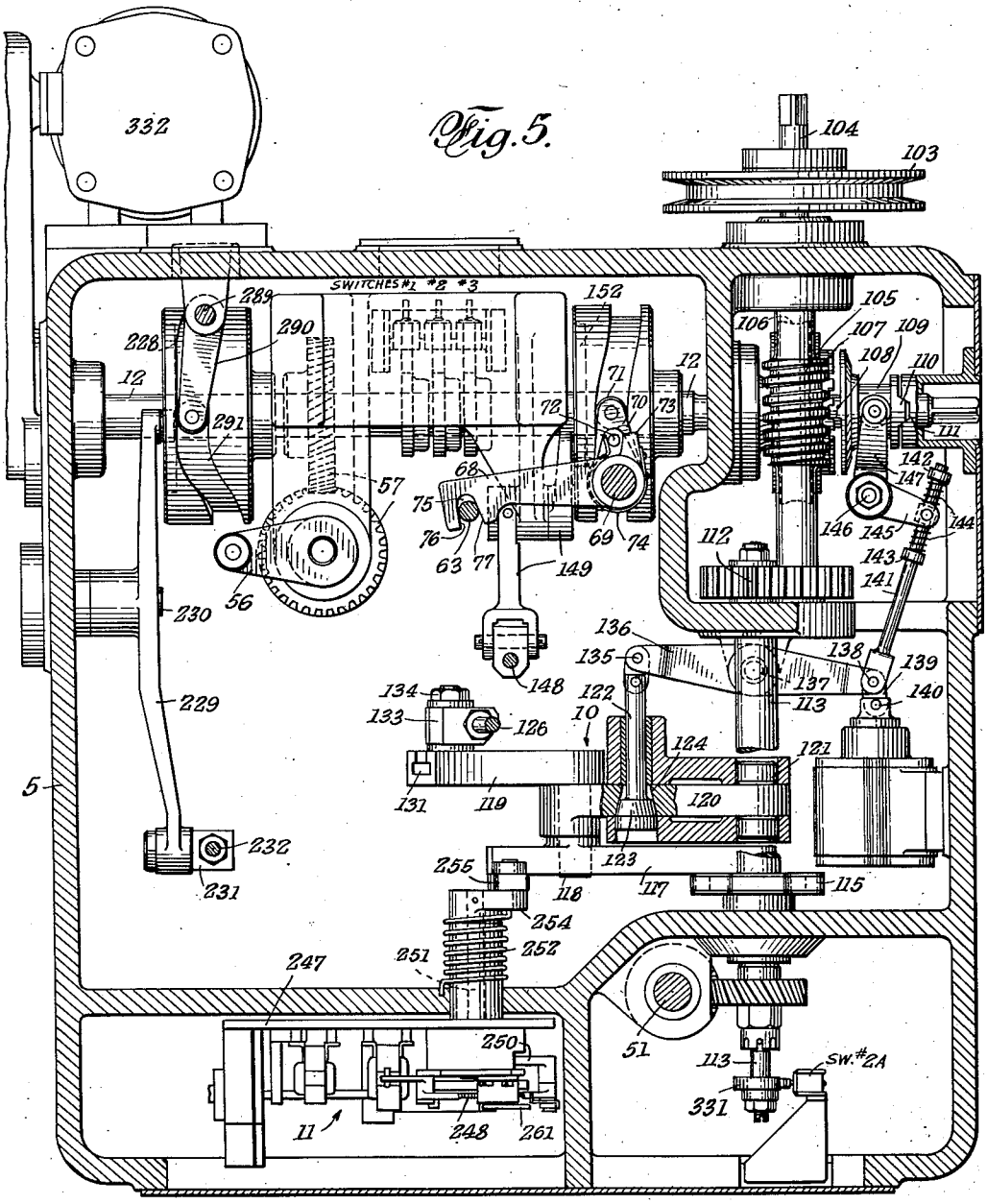
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GRINDER

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Fig. 5.



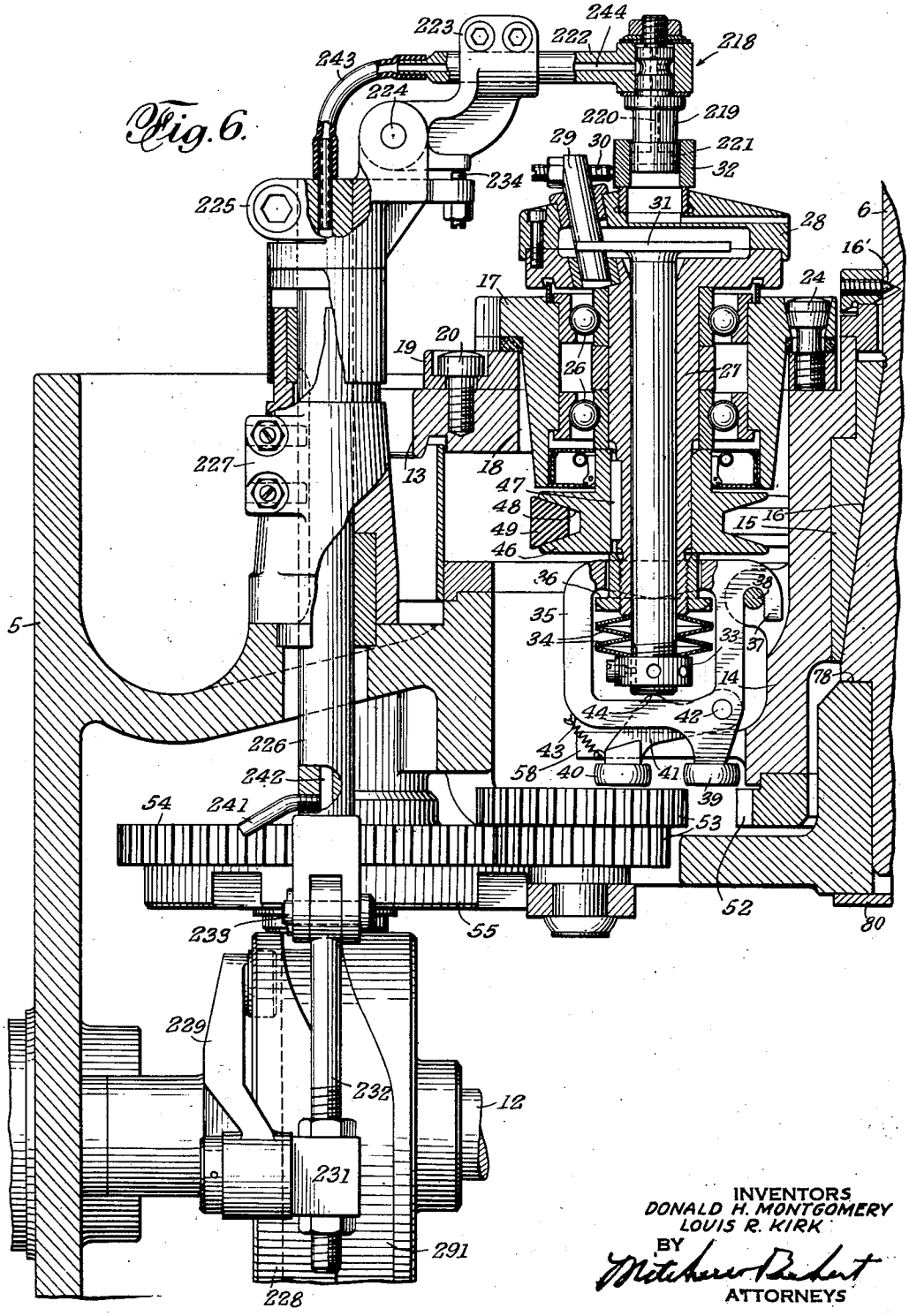
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Fig. 6.



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Fig. 7.

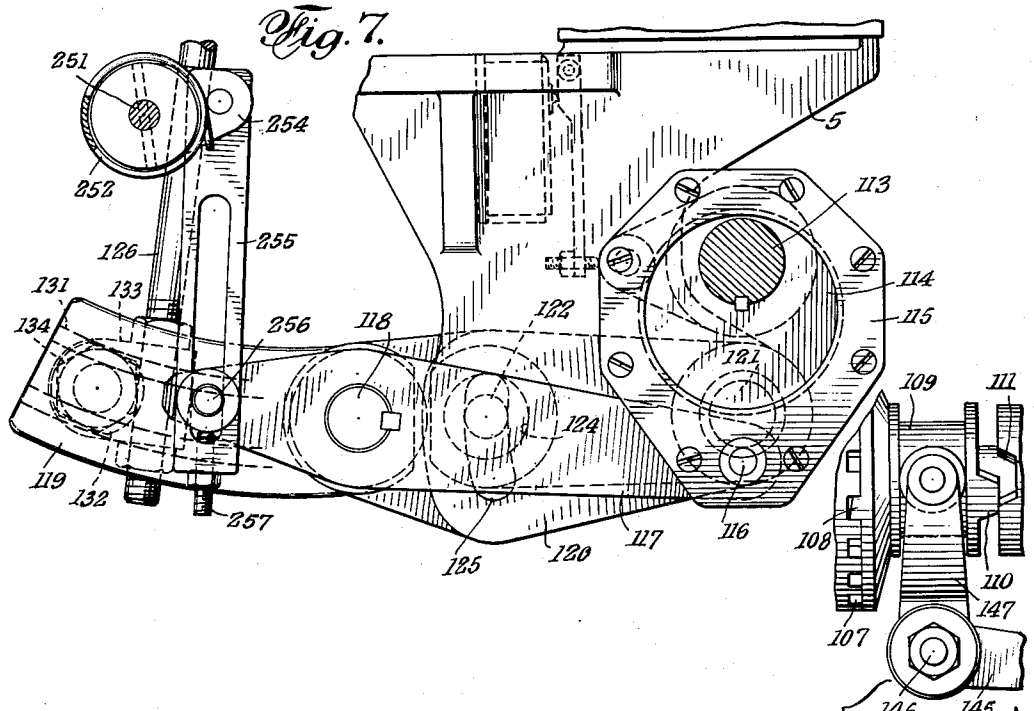
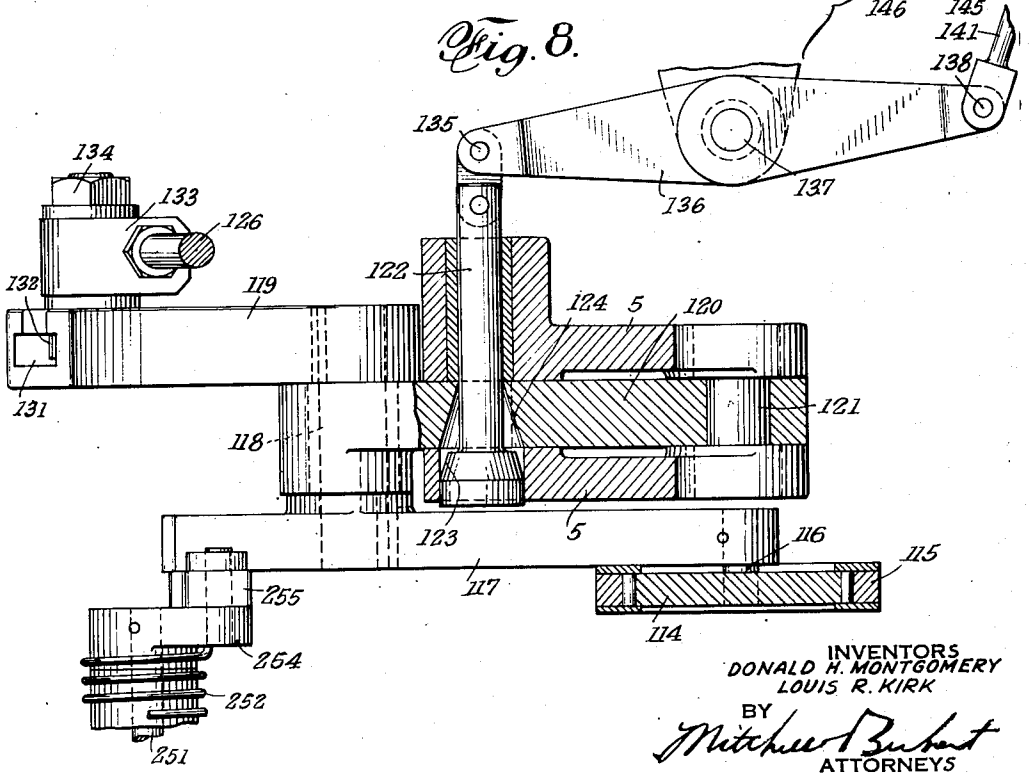


Fig. 8.



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Fig. 9.

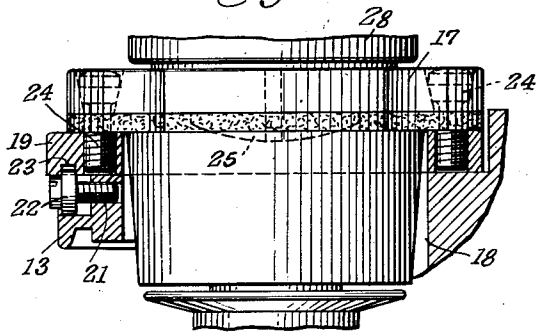


Fig. 10.

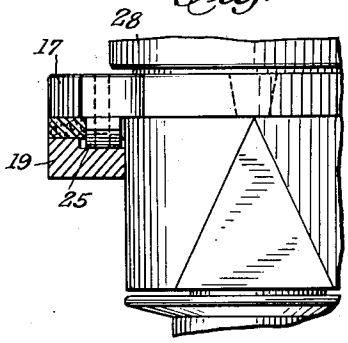


Fig. 11.

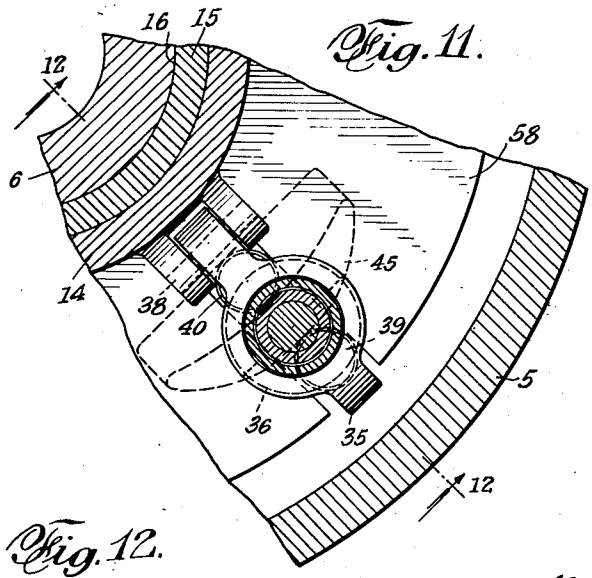


Fig. 13.

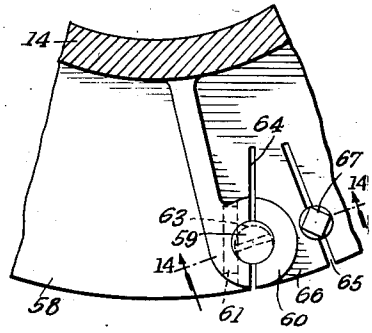


Fig. 12.

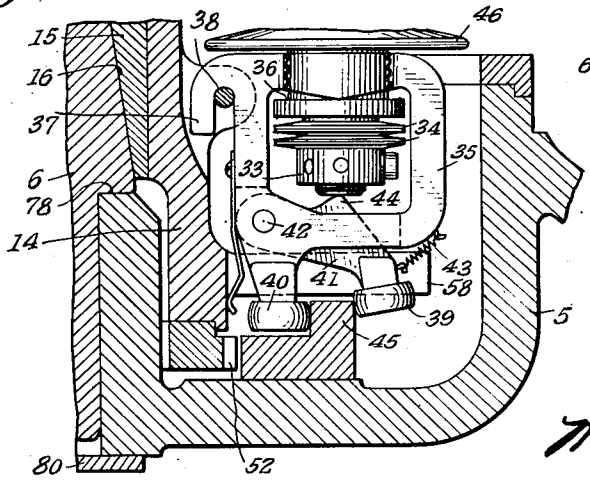
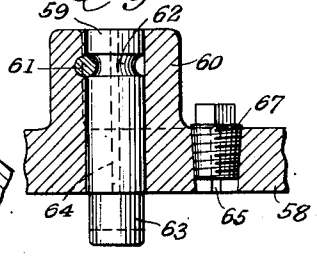


Fig. 14.



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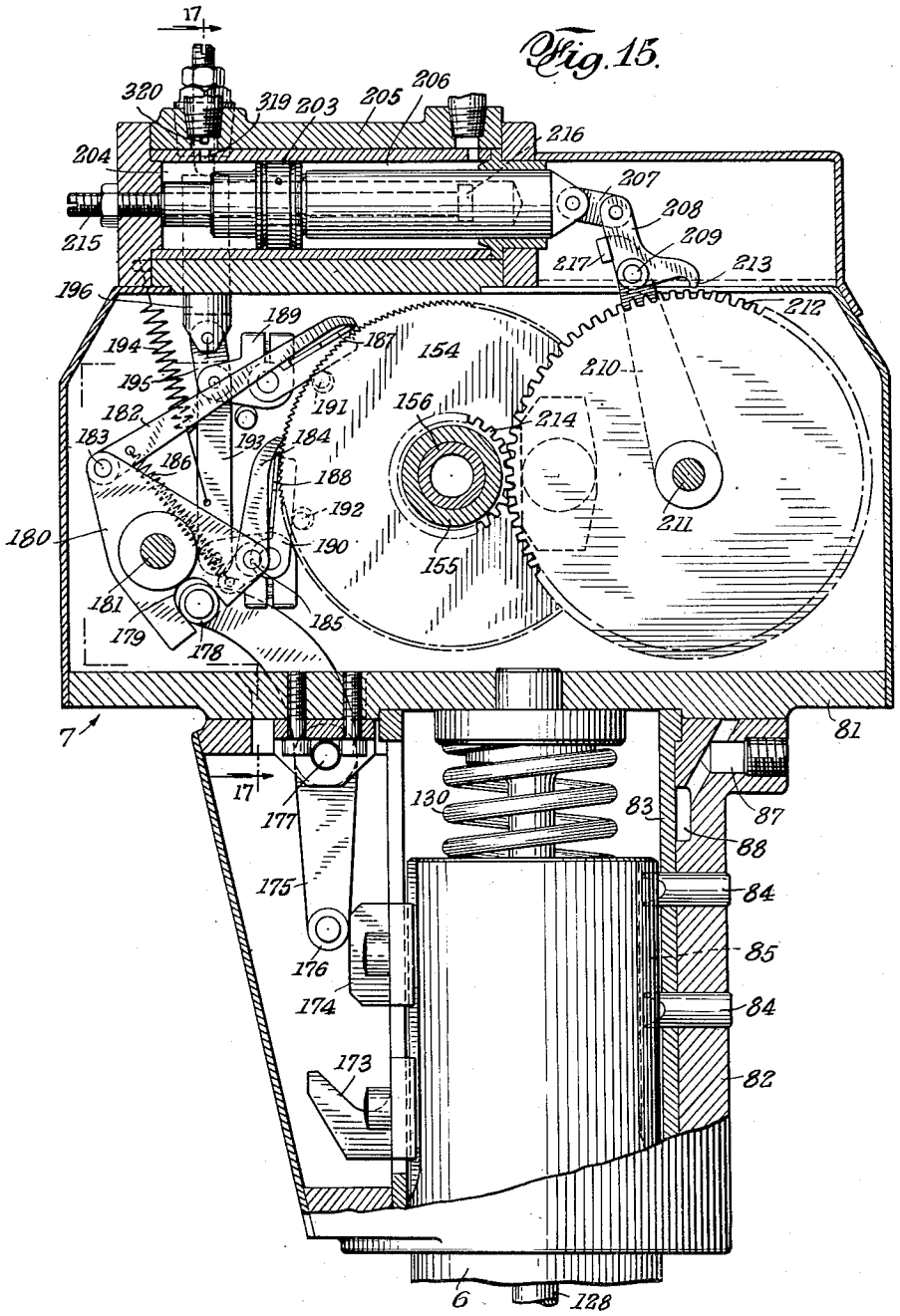
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Fig. 15.



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Fig. 16.

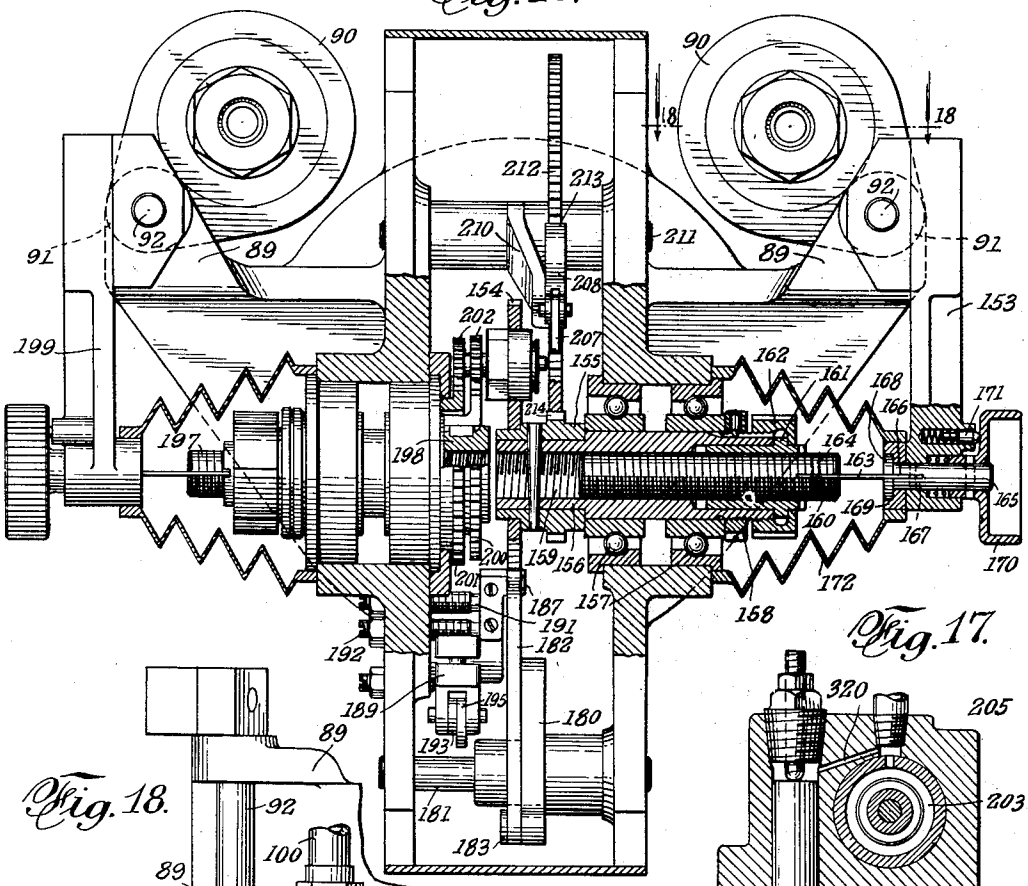


Fig. 17.

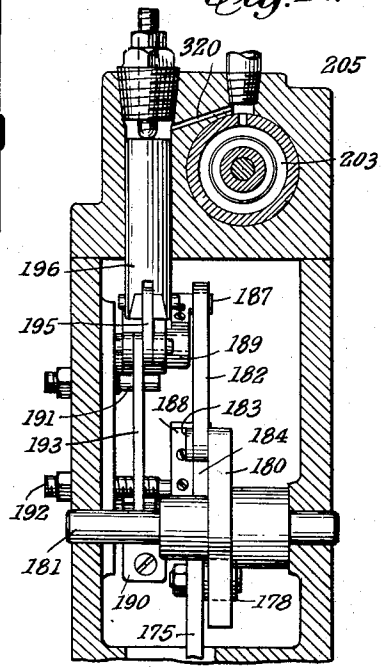
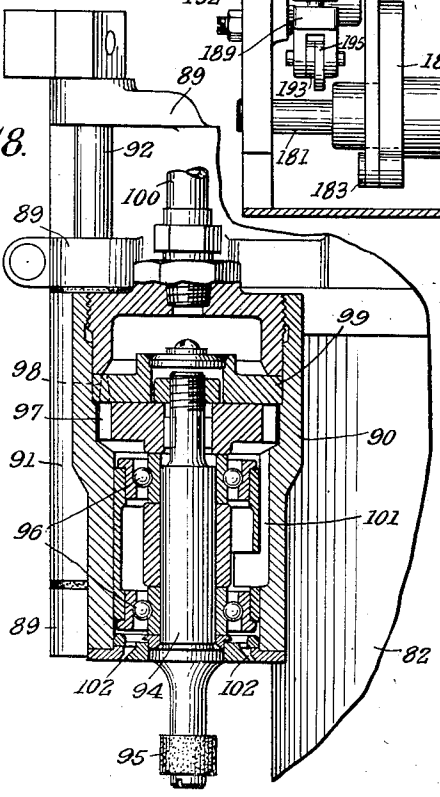


Fig. 18.



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Fig. 19.

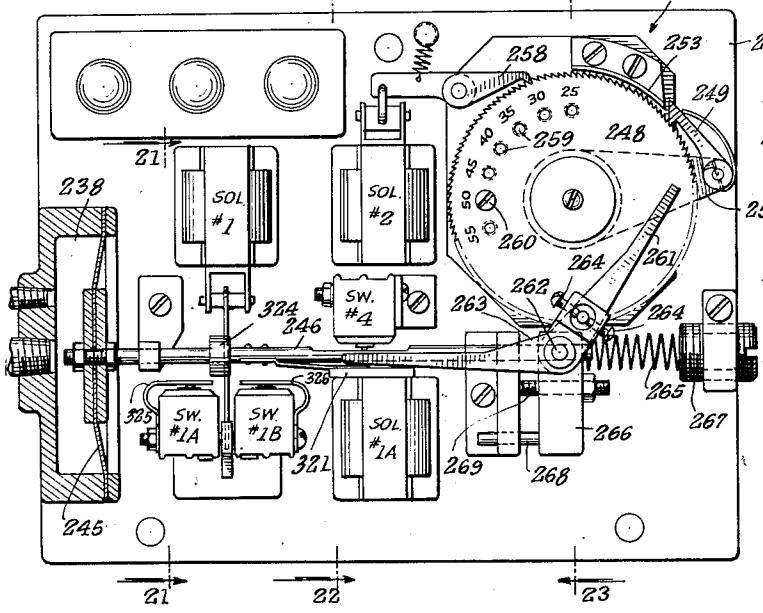


Fig. 20.

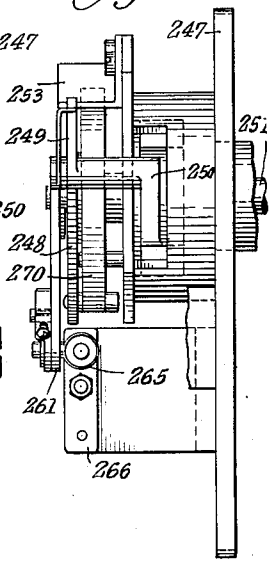


Fig. 21.

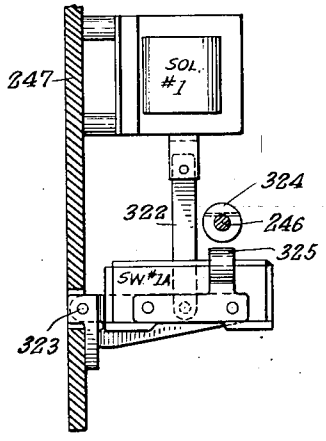


Fig. 22.

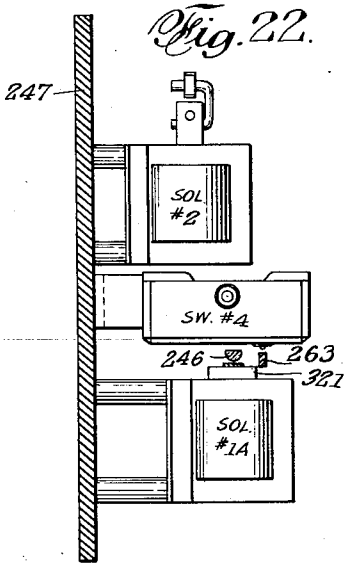
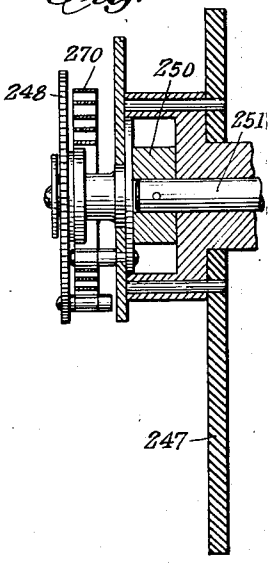


Fig. 23.



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Fig. 24.

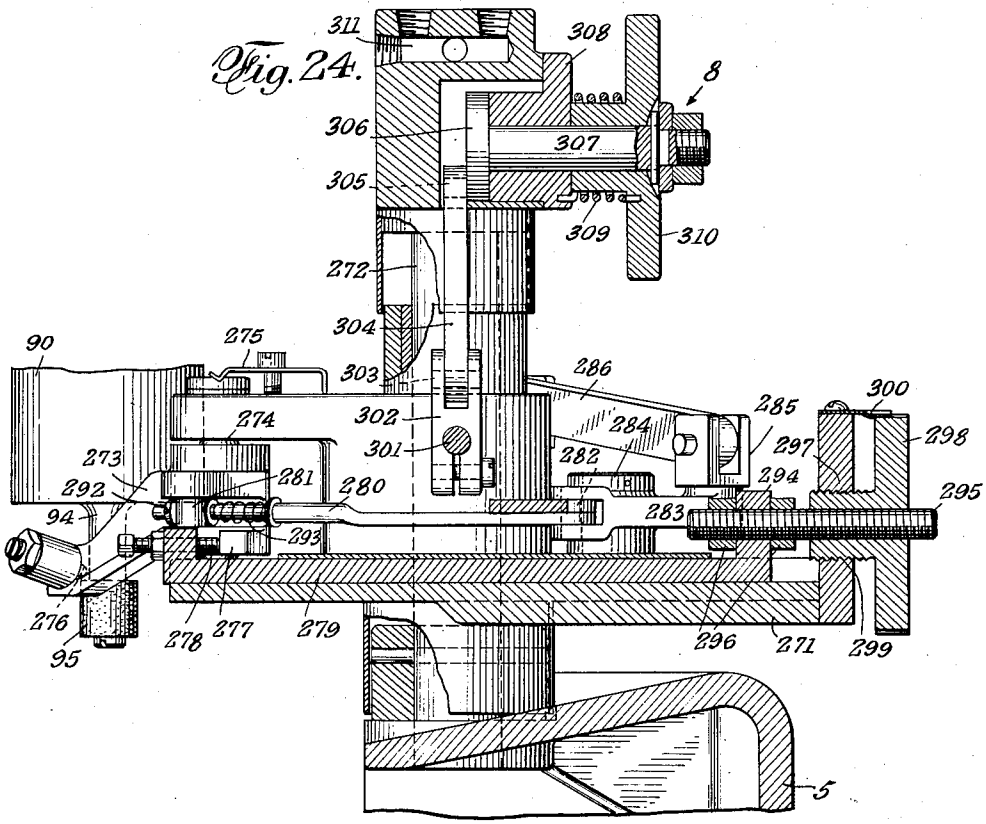
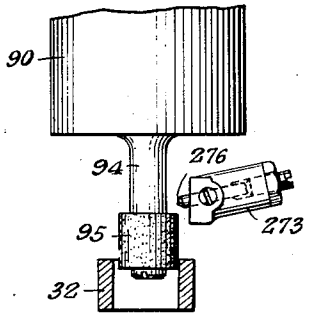


Fig. 25.



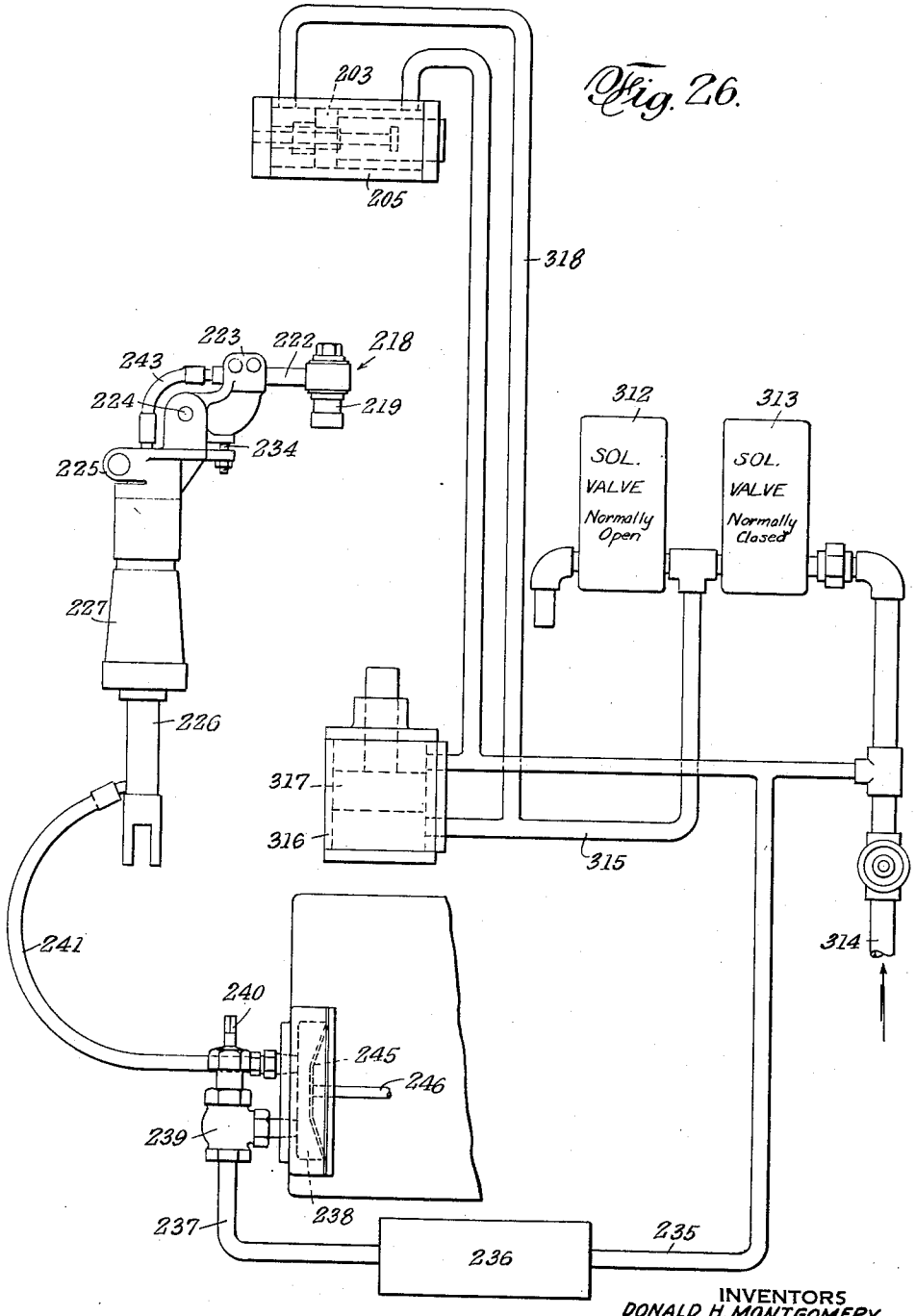
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Fig. 26.



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GRINDER

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Fig. 27.

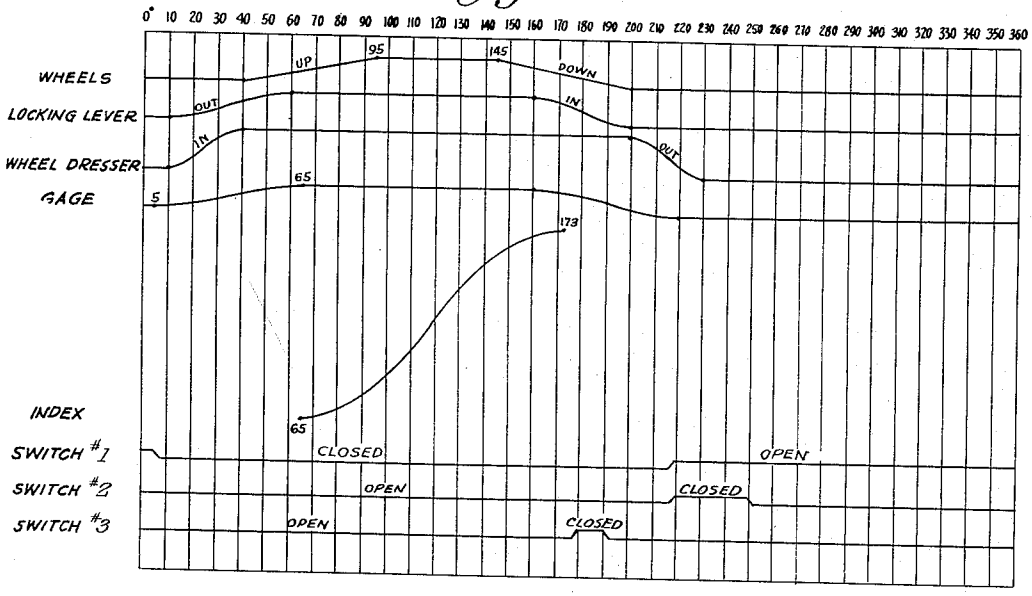
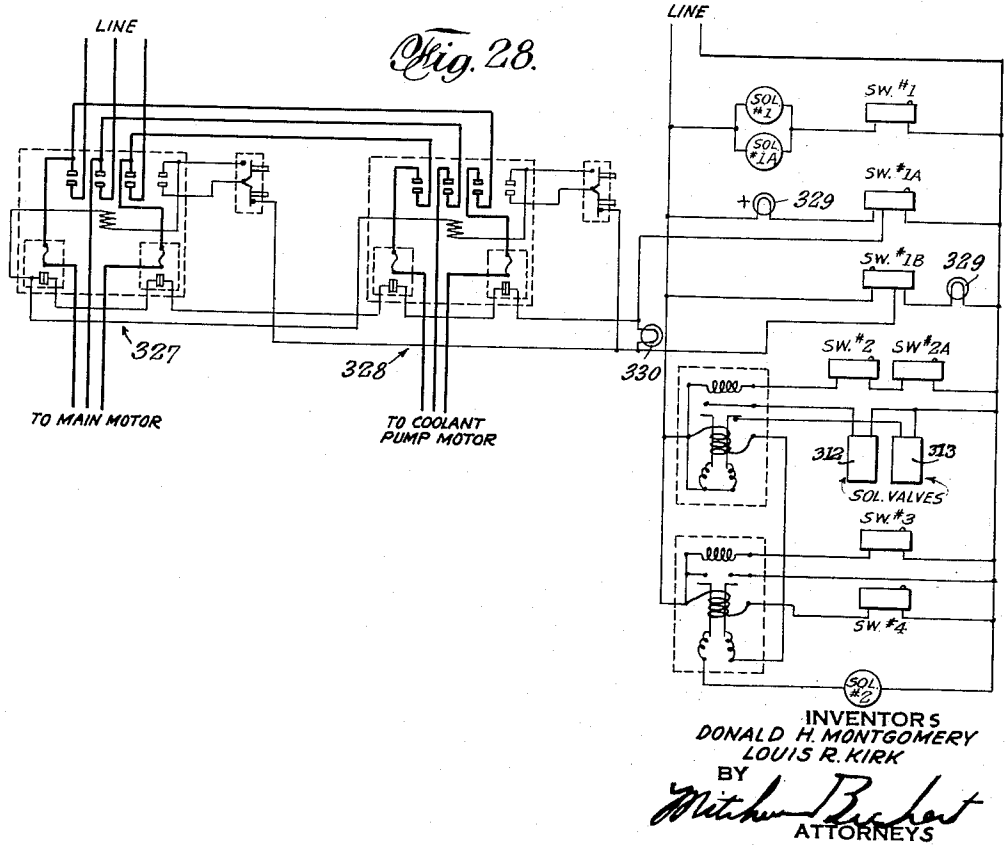


Fig. 28.



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Patented Dec. 12, 1944 2,364,804

UNITED STATES PATENT OFFICE

2,364,804

GRINDER

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Application October 10, 1941, Serial No. 414,394

9 Claims. (Cl. 51—53)

Our invention relates to grinding means.

It is the general object of the invention to provide an improved production grinding machine for producing duplicate pieces with great accuracy.

Another object is to provide improved grinding means arranged so as to compensate for errors in grinding automatically.

A further object is to provide improved grinding means and means for automatically controlling the grinding operation in accordance with the size of a previously ground piece.

More specifically it is an object to vary automatically the number of grinding passes or the feed in a grinding machine in accordance with the size of a previously ground piece.

It is another object to provide improved means for gauging a ground work piece and automatically controlling a grinding machine in accordance with a gauging determination.

It is still another object to provide improved gauging means in connection with a grinding machine.

It is another object to provide improved means for automatically compensating for wear of the abrasive element in a grinding machine.

It is another object to provide improved means for serially grinding work pieces and automatically locating the abrasive surface of the grinding element and the work in proper relative position for each piece to be ground.

It is another object to provide improved dressing means for the abrasive element in a grinding machine.

Another object is to provide a grinding machine for serially grinding work pieces with means for signalling or automatically stopping the machine when a ground work piece is not within the predetermined tolerance limits.

Other objects and various features of novelty and improvement will be hereinafter set forth or will become apparent to those skilled in the art.

Briefly stated, in a preferred form of the invention we provide grinding means, such as a grinding wheel, with means for automatically traversing the work piece and grinding wheel relatively to each other. The grinding may be either external, internal, or formed wheel.

Preferably the work pieces to be ground are held on an indexible turret providing a grinding station and gauging station. For convenience a loading station is also preferably provided; and, if desired, the grinding operation may be accomplished at more than one station. In other words, in a preferred form of machine we employ an indexible turret having chucks for holding the work pieces, and the various chucks are preferably serially indexed from the loading station to one or more grinding stations and a gauging station. The grinding is accomplished by traversing the work piece and the abrasive element relatively to each other, and the number of grinding passes or the amount of the feed is automatically regulated from the gauging station to grind the work pieces to the desired size. The extent of the grinding operation is determined either by determining the number of grinding passes or the feed in accordance with a gauging determination. Such a determination is preferably made on the next previously ground piece so that any error in grinding of a piece will be automatically compensated for in grinding the next piece. In order to provide for very accurate grinding we prefer to dress the grinding wheel before or after, or both before and after, each complete grinding operation. For all normal operations the amount of abrasive removed during grinding may be disregarded and wear may be compensated for by dressing off a certain amount of the wheel for each grinding operation or for a certain number of grinding operations.

It will usually be simpler to regulate the dimensions of the work piece within the required tolerances by controlling the number of passes of the grinding wheel, and the gauging operation not only serves as a check on the ground dimension of the piece being gauged but automatically controls the number of grinding passes of the piece being ground while the last previously ground piece is being gauged. When a ground piece is beyond the limits of tolerance, the machine is preferably stopped or a signal is given, or the machine may be stopped and a signal given.

A preferred embodiment of our invention will be hereinafter more fully described.

In the drawings which show, for illustrative purposes only, a preferred form of the invention—

Fig. 1 is a plan view of a machine illustrating an embodiment of the invention;

Fig. 2 is a sectional view taken substantially in the plane of the line 2—2 of Fig. 1;

Fig. 3 is a central sectional view taken substantially in the plane of the line 3—3 of Fig. 1;

Fig. 4 is a horizontal sectional view taken substantially in the plane of the line 4—4 of Fig. 2;

Fig. 5 is a horizontal sectional view taken substantially in the planes of the line 5—5 of Fig. 2;

Fig. 6 is an enlarged fragmentary sectional view taken substantially in the planes of the line

6—6 of Fig. 1 and illustrating particularly chucking and gauging means;

Fig. 7 is a fragmentary, enlarged detail view of the grinding head reciprocating mechanism;

Fig. 8 is a plan view of the parts shown in Fig. 7, parts being shown in section for purposes of illustration;

Fig. 9 is a fragmentary side view of a chuck, illustrating means for adjusting the chuck for alignment;

Fig. 10 is a fragmentary view in right-hand elevation of parts shown in Fig. 9;

Fig. 11 is a fragmentary, horizontal, sectional view, illustrating parts of the chuck operation mechanism;

Fig. 12 is a sectional view taken substantially in the plane of the line 12—12 of Fig. 11 and showing the chuck operating parts in a chuck open position, as distinguished from the chuck closed position shown in Fig. 6;

Fig. 13 is a fragmentary, horizontal, sectional view through a part of the turret, illustrating an index pin and adjusting and holding means therefor;

Fig. 14 is an enlarged sectional view taken substantially in the plane of the line 14—14 of Fig. 13;

Fig. 15 is an enlarged, vertical, sectional view through a part of the grinding head, illustrating a part of the feed mechanism;

Fig. 16 is a top view in partial section of feed mechanism shown partially in Fig. 15;

Fig. 17 is a sectional view taken substantially in the planes of the line 17—17 of Fig. 15;

Fig. 18 is a sectional view taken substantially in the plane of the line 18—18 of Fig. 16 and illustrating the spindle driving motor and associated parts;

Fig. 19 is a front elevation of counter mechanism mounted in the front lower base portion, as shown in Fig. 5, and illustrating counter and various control mechanisms for the reciprocating grinder head;

Fig. 20 is a view in right-hand elevation of parts shown in Fig. 19, parts being broken away;

Fig. 21 is a fragmentary sectional view taken substantially in the plane of the line 21—21 of Fig. 19;

Fig. 22 is a fragmentary sectional view taken substantially in the plane of the line 22—22 of Fig. 19;

Fig. 23 is a fragmentary sectional view taken substantially in the plane of the line 23—23 of Fig. 19;

Fig. 24 is an enlarged view in partial section of wheel dresser mechanism, the section being taken more or less in the plane of the line 3—3 of Fig. 1;

Fig. 25 is a fragmentary view in elevation of a grinding wheel and driving motor showing the relative location between the grinding wheel, the wheel dresser and the work;

Fig. 26 shows schematically various pneumatic or fluid pressure control circuits for the machine;

Fig. 27 is a developed cam layout indicating operative steps; and

Fig. 28 shows schematically various electric control mechanisms and circuits for the machine.

In the embodiment illustrated there is disclosed an indexible turret having four work stations, one station constituting a loading station; the next station a rough grinding station; a third station a finish grinding station, and a fourth station a gauging station. A work piece which, in the present instance, is, say, a bearing ring to be bore-ground, is mounted in a chuck at the loading station. It is then indexed to the rough grinding station where it is rough ground, then to the finish grinding station where it is finish ground, and then to the gauging station where it is gauged for size. The finished piece after gauging may be discharged at or before reaching the loading station. In connection with the grinding operations, the wheels are dressed preferably both before and after grinding each piece, and the machine is so arranged that the cutting surface of the grinding wheel always starts its feed at a definite position. The arrangement is such that the gauging apparatus gauging the work piece after it has been ground may affect the extent to which the work piece in one of the grinding stations is ground; that is to say, if the finished piece being gauged is over size, the grinding apparatus, while grinding a work piece, is caused to make fewer passes of the grinding wheel or wheels or to feed less, or both, so that the piece being ground, when it reaches the loading station, tends to be ground to the proper size. If the piece being gauged is beyond the tolerance limits the machine may be stopped or a signal given, or both.

The machine illustrated embodies a base 5 to support the working parts. The base more or less centrally thereof may carry a grinding head 7, which in turn carries the abrasive wheel or wheels, feed mechanism and associated parts. The base also supports a dresser head or assembly 8. The turret 9, which bears the chucks (in this case four), is mounted for indexing about the upstanding column 6. The grinding head is reciprocated by mechanism designated generally 10 (Figs. 3, 7, 8), carried within the base or frame member 5, and if desired the head 7 may be resiliently mounted so as to be urged upwardly and thus relieve the reciprocating mechanism of some strains. Means, such as a counter mechanism 11, shown particularly in Figs. 5 and 19, is also carried in the base 5 and serves to determine the amount of grinding, for example, by limiting or in effect counting the number of grinding passes, or the feed, or both. The timing and coordination of the various functions of the machine are controlled by various cams carried by a main cam shaft 12 (Figs. 2, 5) in the base of the machine. It may be here noted that during the grinding operation, that is, while the grinding head is reciprocating, the cam shaft, in the form illustrated, is unclutched from its drive and remains stationary. During the idle time the cam shaft is clutched to its drive, and the various parts actuated by the cam shaft perform their functions.

Turret and chucks

The turret 9 in the form shown comprises a top disk 13 (Figs. 3, 6) integral with a cylindrical skirt 14 surrounding the column 6. A bearing sleeve or bushing 15 is secured within the skirt and has a conical inner bearing surface to fit the conical outer bearing surface 16 on the column 6. Thus, if wear takes place between the turret and the bearing column, the conical bearing surfaces remain tight and the turret will remain concentric with the central column. Taper pin means 16' (Fig. 6) may hold the turret down on its column bearing, as will be clear. The turret is indexed and locked in indexed position by means which will be later described.

The turret carries chucks (in this instance

four), and there are therefore four indexed positions of the turret. As shown more in detail in Fig. 6, each of the chucks embodies a sleeve-like base 17 which extends through an oversize opening 18 in the turret disk 13. The sleeve-like base is itself mounted upon a plate 19 which is adjustably secured to the turret disk as by means of cap screws 20. For fine adjustments of the base plate 19 on the turret disk, we may employ a screw 21 (Fig. 9) threaded into the turret disk and having a flange 22 thereon engageable in a slot or notch 23 in the disk plate 19. By turning the screw 21, the base plate 19 may be very accurately adjusted in a direction radially of the turret so as accurately to position the work held by the chuck. It may be here stated that the grinding wheel is fed in a direction preferably generally radially inwardly of the turret so that accurate radial adjustment of the chucks on the turret is possible where grinding accuracy is required. The sleeve-like base 17 for the chuck is mounted on the base plate 19 and is held thereon by screws 24—24. The chuck base 17 is preferably rockably mounted on the plate 19 as by providing a rocker 25 on the under-face of the chuck base 17, which rocker rests upon a surface of the base plate 19, as will be clear from Figs. 9 and 10. By backing off on one holding screw 24 and taking up on the one on the opposite side of the rockers 25, the chuck axis may be positioned truly parallel to the axis of reciprocation of the grinding head so that the work will be ground in truly cylindrical form instead of in somewhat conical form as would be the case if the axis of the work piece were not held strictly parallel to the axis of the reciprocating head. The sides of the chuck base 17 may be slabbed off as shown in Figs. 9 and 10 to permit considerable rocking adjustment.

The sleeve-like base 17 for the chuck constitutes a housing for a pair of anti-friction bearings 26, which may be preloaded and the inner rings of which carry the chuck spindle 27. At the upper end of the chuck spindle there is a chuck head 28, in which a plurality of chuck jaws are carried. In the form shown, the chuck jaws are cylindrical jaw members 29 slidably mounted in converging bores in the chuck head 28, and each of the jaws is provided with an adjustable work-engaging screw 30. The jaws are actuated by the chuck jaw-actuator 31, which is preferably spring-actuated in one direction and cam-actuated in the other. When the actuator 31 is moved upwardly, the chuck jaws are separated for removal or placing of the work piece, such as a bearing ring 32; and, when the actuator 31 is moved downwardly, the inclination of the jaws 31 causes the work-engaging screws 30 securely to engage the work piece 32 and hold it during the grinding and gauging operations.

The chuck actuator 31 forms part of a chucking rod, which has an adjustable head 33 on the lower end thereof. Resilient means, such as the spring washers 34, are interposed between the adjustable head 33 and the lower end of the chuck spindle 27, so that the chuck actuator 31 is always urged in chuck-closing direction.

The chuck actuator is moved against the springs 34 to open the chucks by means preferably acting upon an indexing movement of the turret. Such means is more clearly disclosed in Figs. 6 and 12. In the form illustrated, a yoke 35 surrounds the lower end of the chuck spindle 27 and has an inturned flange engageable with a flange ring 36 secured to the lower end of the chuck spindle 27. The yoke is held against rotation relatively to the turret as by means of a hook member 37, bent over a pin 38 extending between ears on the turret skirt 14, as will be understood. The yoke 35 is provided with a cam-follower roll 39. A similar roll 40 is carried by a lever 41 pivoted at 42 to the yoke 35. Means, such as a light sprihg 43, keeps the rolls 39—40 separated as shown in Fig. 6. The lever 41 has a nose 44 thereon engageable with the lower end of the chuck actuator rod, so that, when the lever 41 is rocked in a clockwise direction (Fig. 6), the chuck actuator rod and actuator 31 will be moved upwardly against the springs 34 and the chuck opened.

As has been heretofore stated, the chuck preferably is opened upon an indexing movement of the turret. In the form shown, some fixed part such as the base 5 carries a generally arcuate form of cam 45 (Fig. 11) positioned so as to extend between the rolls 39—40 when the turret is indexed. As the rolls 39—40 ride up on the cam 45, they are separated, the lever 41 rocked, and the actuator rod 31 raised so as to open the chuck. The cam 45, as will be understood, is mounted in such position that each chuck will be opened and held open while in loading station. When the turret is indexed and the rolls 39—40 pass beyond the cam 45, it will be clear that the springs 34 will serve to close the chuck on the work piece which will have been inserted while the chuck is open at the loading station. All of the chucks may be duplicates of each other and all may be mounted so as to be accurately adjusted so that duplicate grinding may be performed in each chuck.

The chucks are driven by suitable means, and preferably the chuck in loading station is disengaged from its drive so as to facilitate loading and unloading. In the form shown, the chucks are belt driven, and each chuck when approaching loading station permits its drive pulley to leave the driving connection with the belt. As shown particularly in Figs. 3, 4, and 6, each chuck spindle 27 carries a drive pulley 46, which may be secured to the spindle, as by means of a key 47. Each pulley may have a V-slot 48 thereon for receiving a V-belt 49, which extends about all of the chuck pulleys except that of the chuck in loading station. The belt may be driven by a drive pulley 50 on the driving shaft 51, geared to the main drive shaft to be later described. It will be clear, then, that upon rotation of the drive shaft 51, the chucks in grinding and gauging stations will be rotated and the chuck in loading station will be stationary. Of course, if desired, the drive belt 49 may be trained over idlers so as to be released from the drive pulley in gauging station, as well as in loading station; but, generally speaking, it will be desirable to maintain the work piece in gauging station in rotation.

The turret is indexed by more or less conventional means. As shown particularly in Figs. 3, 4, and 5, the turret skirt carries a gear 52, which through idler gears 53 is driven by a gear 54 carried by and rotatable with a five-slot Geneva disk 55. The roll arm 56 of the Geneva is driven through one-to-one ratio spiral gears 57, one of which is driven by the cam shaft, as will be understood. Since the Geneva has five slots and there are but four chucking stations, the gears 52—53—54 are proportioned as to size so that one rotation of the roll arm 56 will advance each chuck but one station.

The turret is locked in indexed positions, and we have provided means for accurately relating the various locking pins to the turret locking lever. As shown particularly in Figs. 3, 13, and 14, the turret-locking disk 58 carried by the turret skirt 14 has four locking pins thereon corresponding to the four stations. Each locking pin 59 is carried in a cylindrical bore in the disk 58 and upstanding boss 60 thereon. The pin may be held thereon as by means of a securing pin in the boss and extending into a groove 62 in the locking pin, as will be understood. The lower or effective locking portion 63 of the locking pin 59 is slightly eccentric to the main body of the pin 59 so that upon rotation of the pin 59 in its bore, the position of the axis of the eccentric or effective locking portion 63 may be moved in a direction circumferentially of the turret. The pin 59, and consequently the effective portion 63 thereof, after adjustment, is securely clamped to the locking disk 58 by suitable means. In the form shown, the disk is slotted through the bore, as indicated at 64 in Fig. 13, and is further slotted at 65 so as to provide a tongue 66 which will give more or less. A tapered screw plug 67 screws into a tapped opening intersecting the slot 65 so that when the taper plug 67 is screwed up, the tongue 66 will be forced over and the locking pin 59 will be rigidly held in the locking disk, as will be understood.

The locking pins 63 are engaged by a locking lever to hold the turret in indexed positions, as will be clear from Fig. 5. As there shown, the locking arm 68 rocks about the shaft 69, and another arm 70 carrying a cam-follower roll 71 rocks about the same shaft. There is an arm forming part of, or movable with, the arm 70 which carries a pin 72 engageable with an ear 73 on the locking lever 68. The pin 72 is also engageable with a spring 74 opposed to the ear 73. Thus, when the cam arm 70 is rocked in a clockwise direction as viewed in Fig. 5, the pin 72 engaging with the ear 73 will rock the locking lever 68 in a clockwise direction positively and thus release the pin 63 so that the turret may be indexed. When the next pin 63 reaches substantially the position shown in Fig. 5, the cam arm 70 will be rocked in a counterclockwise direction, and the pin 72 will engage the end of the spring 74 carried by the locking lever; whereupon the latter will then be resiliently urged in a counterclockwise direction so as to cause the slot 75 thereon to embrace the sides of the locking pin 63 and thus lock the turret in indexed position. It will be noted that the side 76 of the slot 75 extends in a direction substantially radially of the turret, and the opposite side 77 of the slot acts as a camming surface so that the locking pin 63 is very accurately located by the surface 76 and is cammed into engagement with that surface by the locking surface 77. Needless to say, the cam for actuating the locking lever is so formed and positioned as to withdraw the locking lever just prior to indexing and to move the latter in the engaging direction at just about the end of the indexing motion of the turret.

Grinding head

As has been stated, the grinding head 7 carries the grinding wheel or wheels and the feed mechanism, and the entire head in the preferred form is reciprocated during the grinding operation. The grinding head 7 is mounted for reciprocation on the column 6 which is rigidly mounted in the frame 5. In the form shown (Figs. 3, 12, 15) there is a flange or step-bearing 78 to support the column vertically, and the lower end of the column fits into a bore in the frame to be held against rotation therein as by means of a key 79. Means, such as a plate 80, may be secured to the lower end of the column so as to hold it rigidly in the frame.

As illustrated, the grinding head 7 may be said to include a main base plate 81, which carries the grinding wheel or wheels and the feed mechanism. A cover serves to enhouse the feed mechanism so as to protect the same from dust, coolant, or mechanical injury. The reciprocating head has a cylindrical sleeve 82 depending from the base plate 81 and surrounding the upper end of the column. The sleeve 82 has a bearing bushing 83 therein, fitting the outside of the column and slidable thereon. The grinding head is prevented from rotating, as by means of one or more tapered guide pins or keys 84, secured to the sleeve 82 and extending into a V-slot 85 in the column. The lower end of the slot is preferably closed by a plug 86 to prevent the entry of foreign matter into the bearing between the bushing 83 and the column. The sliding bearing surface between the bushing 83 and the column may be lubricated by a lubricant introduced through the opening 87 and into an annular space 88, from which it may pass through openings to the sliding surfaces.

The grinding head in the present instance carries two grinding wheels, which may be driven by any suitable type of motor; and, in the present instance, we have disclosed direct-driving motors in the form of air turbines. As illustrated (Figs. 2, 16, 18), the main base plate 81 and the bearing sleeve 82 have ears or bearing projections 89—89 for supporting the grinding wheel motors. Each motor casing 90 has a hinge projection 91 fitting between the ears 89—89, and hinge pintle means 92 extends through the hinge projection 91 and into the ears. The pintle means 92 may have opposed cone bearings 93—93 in the ears 89 so that the motor casing and consequently the grinding wheel will always be held in line with the axis of the hinge pintle regardless of slight wear. The hinge pintle is preferably rigidly carried by the hinge projection 91 of the motor casing, and the hinge pintle means 92 extends upwardly for connection with the feed mechanism, as will be later described.

The grinding spindle 94 carrying the grinding wheel 95 at the lower end is mounted in the motor casing 90 preferably on ball bearings 96, which may be preloaded to give great stability to the spindle in all directions. At the upper end of the grinding spindle 94, there is a turbine rotor having blade 97 opposed to the nozzles 98 in the top plate 99 in the turbine casing. Motive fluid, such as compressed air, is introduced to the air motor through a hose connection 100. The entering air preferably carries lubricant in the form of an oil mist for the ball bearings 96. The air and entrained lubricant, after passing the rotor blades 97, may pass down through the upper bearing 96 and in order to assure lubrication of the lower bearing 96, there may be a by-pass 101 so that some of the air discharging from the turbine will not pass through the upper bearing but will pass around it and to the lower bearing. In the preferred form, the exhaust air from the turbine is directed in such fashion as to form an air shield about the grinding wheel and thus tend to prevent splashing

of coolant and the like. In the form shown, the lower closure plate of the motor casing is provided with generally outwardly and downwardly directed exhaust nozzles 102 so that the escaping air in effect will form a cone curtain extending downwardly around the grinding wheel and thus act as a shield for the coolant, etc. The air motor may be run at exceedingly high speeds, which high speeds are desirable when very small pieces are being ground internally, and consequently when very small grinding wheels must be used. However, it is to be understood that the grinding wheels may be otherwise driven.

Reciprocating mechanism

The grinding wheel or wheels and the work are traversed relatively to each other in this case by reciprocating the grinding head so as to cause the grinding wheels to make the desired number of grinding passes. The reciprocating motion is derived from the main drive, which may be of any desired type. In the form shown (Figs. 1, 2, 4, 5) the main drive pulley 103 carried by the main drive shaft 104 is driven by a belt from any suitable driving motor. The shaft 104 carries a worm 105, driving a worm wheel 106, which is freely rotatable on the shaft 12. The worm wheel 106 has a clutch face 107, to be engaged by a driven clutch face 108 on the main clutch spool 109 splined to the main cam shaft 12; and, in the form illustrated, the main clutch may be disengaged at only one point, namely, when the single tooth 110 on the clutch spool 109 is in position to drop into the notch 111 on the frame of the machine. The main drive shaft 104 through change gears 112 drives a countershaft 113, from which the reciprocating motion of the grinding head is derived.

As illustrated (Figs. 2, 5, 7, 8) the countershaft 113 carries an eccentric 114 operating the eccentric strap 115. Needle bearings or other anti-friction bearing members may be interposed between the eccentric and its strap, if desired. The eccentric strap 115 is pivotally secured by means of a stub shaft 116 to a reciprocating lever 117. The reciprocating lever is fixedly secured to a shaft 118, which shaft fixedly carries an arm 119, so that the lever 117 and arm 119, both being keyed to the shaft 118, constitute in effect one single lever. A part of the frame 5 has a link 120 pivotally mounted thereon by means of a shaft or pin 121. This shaft 121 is mounted in spaced-apart bearings in the frame; and the link 120, mounted on the shaft, is guided between the spaced-apart frame portions, as will be clear from Fig. 8. The link 120 has a bearing on the shaft 118 and the latter shaft is freely rotatable in that bearing. The link 120 is so arranged that it may be releasably secured to the frame 5 and in effect become temporarily an integral part thereof, so that the eccentric may rock the lever 117—119 freely about the temporarily fixed bearing for the pivot shaft 118. In the form shown the frame slidably carries a locking pin 122, having a taper head 123 at the free end. The link 120 has a taper seat 124 to receive the head 123, so as to securely lock the link 120 to the locking pin seated in the seat 124. The link 120 is also provided with an arcuate slot 125 intersecting the seat 124, as clearly shown in Fig. 7. When the reciprocable locking pin 122 is moved out, that is, downwardly as viewed in Fig. 8, so as to disengage the head 123 from the seat 124, the link 120 may be freely rocked about its pivot shaft 121, and the pin may freely move through the arcuate slot, as will be understood. The purpose of the linkage just described is to reciprocate the grinding head when the pin 122 is "in," or raised as viewed in Fig. 8, and for rendering the eccentric reciprocating mechanism ineffective when the locking pin is "out."

As illustrated (Figs. 3, 5, 7, 8) the lever 119 is pivotally secured to a connecting rod or link 126, secured to a crosshead 127 (Fig. 3), which crosshead carries an actuating rod 128, secured to the main base 81 of the reciprocating grinding head 7. In the preferred form the main column has an abutment plate 129 therein, acting as a seat for a coiled compression spring 130, which acts beneath the reciprocating head so as resiliently to support and raise the grinding head when the latter is freed from the reciprocating linkage.

In order to adjust the stroke of the grinding head the pivotal connection between the lever 119 and the connecting link 126 is adjustable. In the form shown the lever 119 has a longitudinally extending T-slot 131 for receiving a securing bolt 132, adjustable in the slot and carrying a bearing member 133 to which the rod 126 is secured. Thus, when it is desired to change the stroke, the bolt in the T-slot is released by backing off on the securing nut 134, after which the bolt 132 may be moved to the desired position in the slot and thus change the effective length of the lever 119. After the desired point of adjustment has been reached the securing nut 134 is, of course, turned up to maintain the adjustment.

The operation of the reciprocating mechanism is as follows:

When the tapered locking pin 123 is seated in the seat 124 of the link 120, the latter in effect becomes a part of the frame, and the eccentric 114 will serve to rock the lever 117—119 about the now fixed pivot axis of shaft 118 to reciprocate the grinding head. It will be seen that the compression spring 130 relieves the reciprocating mechanism of considerable strain and facilitates reciprocation. After the grinding operation has been completed, the reciprocating linkage is rendered ineffective, and the grinding head is raised by the spring 130 to its uppermost or retracted position. The ineffective linkage results from dropping the tapered head 123 out of its seat 124 into the position shown in Fig. 8. When the taper-head pin is thus positioned, the link 120 is no longer coupled to the frame and is, of course, free to oscillate about the pivot shaft 121, this oscillation being permitted, as heretofore indicated, by the arcuate slot 125. When the pin head 123 is withdrawn, the grinding head will move to its uppermost position and therefore carry the free end of the lever 119 to its highest position. The eccentric, acting on the right-hand end of the lever 117, will therefore raise and lower that end; and, since the left-hand end of the lever 119 is, in effect, fixed at its highest position, the lever 117 will carry the pin 116 and with it the left-hand end of the link 120 up and down—thus simply permitting the lever 117—119 to rock freely about the axis of the bearing 133 at the end of the connecting rod 126 without moving the reciprocating head. When the tapered head 123 is again seated in the seat 124, the link 120 is once more locked to the frame, thus making the shaft 118 a stationary pivot axis for the lever 117—119 to permit reciprocation of the grinding head again.

The locking pin 122 is automatically actuated

at the proper times during the cycle of the machine. As illustrated (Figs. 5, 8), the locking pin 122 is pivoted at 135 to a lever 136, pivotally carried by the frame at 137. The lever 136 at its opposite end is pivoted at 138 to a link 139, which is itself pivoted at 140 to an actuating piston, the purpose and function of which will be later described. The lever 136 is also pivoted at the point 138 to a link 141, which carries a pair of abutment heads 142—143 to act as abutments for springs 144 on opposite sides of a sliding head on the bell crank lever 145, which is pivoted to the frame at 146. The free end of the bell crank lever 145 comprises a fork 147 for shifting the clutch sleeve 109, heretofore mentioned.

Thus, during the grinding operation, the grinding head, carrying one or more grinding wheels, is reciprocated so as to effect the requisite number of grinding passes. When the grinding operation has been completed, the tapered locking pin 123 is withdrawn from its seat so as to release the reciprocating linkage, and the grinding head moves to its upper position under the influence of the coil spring 130. In order to prevent the grinding head from springing up too rapidly and also to lower the grinding head to such a position that the tapered locking pin 123 may be reengaged with its seat 124 for the next grinding cycle, we provide retarding and actuating means such as cam means. In the form shown (Figs. 3, 5), there is a link 148 pivotally secured at one end to the cross-head 127 and at the opposite end to a lever 149 pivoted to the frame at 150. The lever carries a cam roll 151 to engage a face cam 152 on the cam drum carried by the main cam shaft 12. The cam drum, it will be recalled, is stationary during the grinding operation, and the cam 152 will be positioned angularly of the cam shaft so that the cam roll 151 will engage the cam 152 when the grinding head has moved to a position just slightly higher than its uppermost grinding position, and also so that, when the cam shaft is rotated, the upward movement of the grinding head under the influence of the spring 130 will be retarded. Just prior to the next grinding operation, the cam 152 will slowly lower the grinding head to such an extent that the tapered locking pin 123 may readily find its seat 124. A further purpose of retarding the upward speed of the grinding head between grinding operations and of lowering the grinding head at a definite relatively slow rate, is to permit wheel dressers, to be later described, to act on the grinding wheels for dressing the same.

Feed

During the reciprocation of the grinding head the grinding wheel or wheels and the work will be advanced or fed relatively to each other. The feed mechanism in the form shown feeds the wheels, is carried by the grinding head, and is actuated upon the reciprocation of the grinding head by the cam-rocker means or the like. As has been heretofore stated the grinding wheels are mounted for swinging about the axis of the pintle 92 (Figs. 2, 16). A feed arm 153 may be secured to the pintle 92, rigid with the wheel mount, and the feeding of the grinding wheel accomplished by swinging the feed arm 153 about the axis of the pintle 92. Both the rough and finish grinding wheels may be and preferably are mounted in the same manner and fed in the same general manner. Feeding by swinging the feed arm 153 may be accomplished as follows:

The grinding head carries a ratchet wheel 154 (Figs. 15, 16) mounted upon a sleeve 155, which is in turn mounted upon, and preferably pinned to, a bearing quill 156. The quill is preferably mounted on anti-friction bearings 157 in the frame of the reciprocating head. The quill 156 may be mounted against endwise movement by means of the angular contact bearings, the outer rings of which are shouldered to fit opposite abutment surfaces on the grind-head frame, as will be clear from Fig. 16. A nut 158, threaded onto the quill and abutting the inner ring of one bearing, serves to adjust the pre-load on the bearings and prevent endwise movement of the quill. The quill may be internally threaded, as indicated at 159, for receiving a threaded feed-screw 160. In order to take up any possible backlash in the quill and feed screw we may provide a gland 161, threaded on the feed screw 160 and adjustably held on the quill, as by means of a gland nut 162. By turning up on the gland nut it will be understood that all backlash may be taken out.

The feed screw is connected to the feed arm 153 by suitable means and, in the form shown, we employ a flat plate or spring-like element 163, which slidably fits in a slot in the feed screw and which may be pinned therein by a transverse pin 164, so that the plate member 163 may move relatively to the feed screw in the direction of its flat width and may yield in a direction across the flat width, due to its inherent yieldability. The other end of the plate connector 163 may be similarly connected to a hand-operated shaft 165, that is, by means of a slot connection 166 and transverse pin 167. The hand-operated shaft is held against endwise movement in the arm 153, as by having a head 168 thereon abutting against a thrust washer 169 on the feed arm 153, so that outward movement, that is, movement toward the right of the feed screw 160, will positively swing the arm 153 in a counterclockwise direction, which is the feeding direction in the case of the roughing wheel located at the right in Fig. 16. The shaft 165 may be rotated for grinding wheel adjustment, as by means of a hand wheel 170 and may be held as by means of a spring-pressed detent 171 in any manually rotated position. A protecting boot 172 may be employed for protecting the feed screw and adjacent parts. Since the quill 156 is held against endwise movement in the grinding head, rotation of the feed screw 160 relatively to the quill, as by means of the hand wheel 170 or by means of the ratchet wheel 154, to be further described, moves the grinding wheel in the feeding or retracting direction, as will be understood. The hand wheel 170 is employed for rapid rotation of the feed screw for adjusting the cutting wheel, as, for example, when a new wheel is put in place.

The automatic feed may be effected through the ratchet wheel 154 by means now to be described. The column 6 may be provided with a fixed cam (Figs. 3, 15), which may be adjusted up and down on the column, as may be desired. When it is desired to feed on both the up and down strokes of the grinding head, the column is preferably provided with a second cam 174, which will serve to feed the grinding wheels on the up-stroke. As illustrated, there is a lever 175 having a cam roller 176 for engagement with the cam 173 on the down-stroke and with the cam 174 on the up-stroke. The lever 175 is pivoted to the reciprocating grinding head at 177 and the upper end of the lever may have a roll

178, working in a slot 179 in a pawl lever 180, pivoted to the grinding head at 181. A pawl 182 is pivoted to the lever 180 at 183 and, if desired, a second pawl 184 is pivoted to the lever 180 at 185. A tension spring 186 may be employed for urging both pawls into engagement with the ratchet wheel 154. Thus, when the grinding head reciprocates, the lever roll 176 will engage the cams 173—174 alternately, to rock the lever and cause the pawls alternately to feed the ratchet wheel 154 in a clockwise direction, as viewed in Fig. 15. The number of teeth on the ratchet wheel 154 which will be advanced by the pawls 182—184 may be determined by shrouds 187—188, which are adjustably mounted on pivotally mounted levers 189—190, clearly shown in Fig. 15. The shroud levers 189—190 may be limited in their movements in one direction, as by adjustable eccentric stop pins 191—192, as will be understood.

The two shroud levers are preferably linked together by means of a connecting link 193, and means, such as a tension spring 194, serve to urge both shroud levers into their operative positions shown in Fig. 15. The link 193 is connected as by means of a link 195 to an actuator, such as the air actuated piston 196, so that, when the piston 196 is depressed as viewed in Fig. 15, the shrouds will be actuated to lift the pawls into inoperative position and to hold them in such position while the feed ratchet 154 is returned after the grinding operation has been completed.

During the grinding operation the parts may occupy substantially the positions shown in Fig. 15. Thus, when the grinding head has been raised to the position there shown, the lever 175 will have been rocked by the cam 174 and the ratchet wheel will have been advanced by the lower pawl 184 one tooth, or any number of teeth, as determined by the adjusted position of the shroud 188 controlling the position of engagement of the pawl with the ratchet wheel. When the grinding head is lowered the lever 175 will be rocked by the lower cam 173 so as to retract the lower pawl 184 and advance the upper pawl 182 to feed the ratchet wheel 154 one tooth or such number of teeth as may be determined by the position of the adjustable shroud 187. Thus, with two pawls, there will be a feed movement of the ratchet wheel on both the up and down stroke of the grinding head. It may be here stated that each pawl need not advance the ratchet wheel one complete tooth. One pawl, for example, may advance the ratchet wheel, say, a distance of half a tooth, and the other pawl may advance the ratchet wheel the distance of another half tooth, so that for each complete reciprocation the ratchet wheel will be advanced one full tooth.

The ratchet wheel 154, as has been heretofore stated, is carried with the threaded feed quill 156 so that when the ratchet wheel is rotated, the feed quill is rotated; and, since in the present embodiment the feed screw 160 is held against rotation by the means heretofore described, including the detent 171, the feed screw, and consequently the feed arm 153, will be moved outwardly and the roughing wheel will be moved inwardly by an amount determined by the feed of the ratchet wheel and the lead of the thread on the feed screw. The feed of the roughing wheel will therefore be determined directly by the lead of the thread on the feed screw 160. The feed of the roughing wheel will ordinarily be substantially greater than the feed of the finish wheel, but the feed of both wheels is preferably accomplished by the same means, namely, the ratchet wheel 154.

In the form shown the finish wheel is fed by a feed screw 197 working in a feed quill 198 in the same manner as heretofore described in connection with the roughing wheel. The feed screw 197, connected through the finish wheel feed arm 199, serves to swing that arm and with it the finish wheel located at the left of Fig. 16 in a clockwise or feeding direction. We prefer to employ a differential gearing for driving the feed quill of the finish wheel from the ratchet wheel 154. As illustrated, the feed quill 198 has a ring gear 200 keyed thereto, and a ring gear 201 having a slightly larger number of teeth than ring gear 200 is fixedly secured to the frame of the grinding head. A planet gear 202 is carried by the ratchet wheel 154, and the gears of the unit 202 mesh, respectively, with the ring gears 200—201, so that upon rotation of the ratchet wheel 154 the feed quill 200 will be rotated relatively to the feed screw 197 but at a very much slower rate than the direct driven feed quill 156 for the rough grinding wheel, Thus, during the grinding operation, that is, during the reciprocation of the grinding head, the roughing wheel will be fed at one rate and the finish wheel, operating upon a piece previously rough ground by the rough grinding wheel, will be fed at a very much smaller and therefore proper finish grinding rate.

When the grinding operation has been completed the grinding wheels are retracted an amount very slightly less than the amount that they have been fed, and, as will be described, the wheels are dressed for each piece ground. In the form shown retraction of the grinding wheels is accomplished in the following manner:

The air piston 196 (Fig. 15) is actuated, as will be later described in connection with the operation of the whole machine, and such actuation of the piston 196 swings the shroud levers 189—190 so as to disengage both pawls 182—184 from the ratchet wheel. At the same time or immediately thereafter the differential piston 203 is moved toward the right, as viewed in Fig. 15, by air pressure admitted to the head end 204 of the cylinder 205. It may be here stated that during the grinding operation the differential piston 203 has been held in its retracted or left-hand position by air pressure on the tail end 206 of the cylinder. When the differential piston 203 moves to the right, it acts through a link 207 on a bell crank lever 208 pivotally connected at 209 to an arm 210 mounted for swinging about the axis of the shaft 211 carried by the grinding head. A retracting gear 212 is mounted for rotation about the axis of shaft 211, and the bell crank 208 is provided with a single tooth or pawl nose 213 to engage a tooth of the retractor gear 212. The retractor gear 212 meshes with a pinion formed on the sleeve 155, which, as heretofore stated, is fixedly carried by the quill 156. Upon movement of the differential piston, the retractor gear will be rotated in a clockwise direction; and it will be understood that the ratchet wheel 154 will be returned thereby.

The extent to which the ratchet wheel will be retracted may be determined by limiting the travel of the differential piston 203. Such limiting means may comprise a rod 215 adjustably secured to the head end of the cylinder 205 and provided with a stop head 216 to engage an abut-

ment surface on a part of the differential piston so as to limit its stroke toward the right. After the ratchet 154 has been retracted, the air pressure will be released, as later described, and the air piston 196 will be raised as by means of a spring 194 to drop the shrouds and pawls into operative positions again. At the same time, the differential piston 203 will be returned toward the left and the bell crank 208 engaging the abutment 217 will return the arm 210 to about the position shown.

For any particular pieces to be ground, the operator, in setting up the machine, estimates the number of grinding passes required for grinding the piece to the required dimension. By counter mechanism, to be later described, the estimated number of passes will be made and the feed ratchet 154 will, of course, be rotated a definite amount corresponding to the estimated number of passes.

After each grinding operation, in order to retract the feed wheel by an amount very slightly less than the amount fed, the stroke of the differential piston 203 may be limited by the adjusting strop screw 215 so as to return the feed ratchet 154 by the amount fed less, say, one ratchet tooth or so. By retracting the feed wheels, after each grinding cycle, an amount slightly less than the amount fed, the grinding wheels will be located so that some appreciable amount may be dressed off of each wheel or wheels by the dressing tools to be later described and the dressed cutting surface of the grinding wheel will always start a new grinding operation in the same grinding position.

Gauging and control

Each work piece or selected work pieces are gauged subsequent to grinding; and, in the preferred form, the grinding operation is automatically controlled so as to compensate for inaccuracies as determined by the piece being gauged. In the preferred form illustrated, one of the stations of the indexible turret is a gauging station, and we prefer that this gauging station be the station following the finish grinding station so that finish-ground pieces are gauged. The gauging may be performed by various mechanisms, but we prefer to employ a fluid-pressure type of gauge or feeler and employ fluid pressure for automatically controlling the grinding operation so as to compensate for errors in grinding appearing in the piece being gauged.

As shown in Figs. 1, 2, 3, 4, and in detail in Fig. 6, the gauge, designated generally 218, is mounted for gauging at the station following the finish grinding station. The gauge is preferably of the plug type (for internal grinding) as shown in detail in Fig. 6. The gauge plug 219 has an air passage 220 leading to generally outwardly or radially directed passages 221 opening adjacent the ground surface to be gauged. There are preferably a plurality of passages 221 or an annular passage so that the air is discharged circumferentially of the plug gauge, that is, between the outer circumference of the gauge and the wall of the bore in a ground ring 32. The gauge plug 219 may be mounted in a head 222 adjustably carried on a rocking bracket 223, which is pivotally secured at 224 to the head 225 on an actuating bar 226. The actuating bar 226 is slidably mounted in bearings in an upright column 227 mounted on the main frame 5 of the machine, as will be clear. Motion of the bar 226 will hereinafter be described in connection with positioning the gauge within the ring 32 and withdrawing the gauge after the gauging operation.

Cam means are employed to move the actuating bar 226 in timed relation with the feed functions of the machine. In the form shown (Figs. 5, 6) a cam 228 is provided on a cam drum on the main cam shaft 12. The cam 228 is designed and positioned so as to actuate the gauge lever 229, pivoted to the frame 5 at 230. The free end of the gauge lever 229 carries a pivotally mounted head 231, to which one end of a connecting rod or link 232 is adjustably connected. The other end of the connecting-rod link 232 is pivotally connected by a pin 233 to the lower end of the gauge actuating bar 226. Thus, when the turret has been indexed to bring the finish-ground piece to the gauging station, the cam 228 will rock or permit the rocking of the lever 229 so as to lower the gauge plug 219 into the bore of the ground piece 32, as will be understood. As stated, the gauge plug is carried by a head pivotally mounted at 224 so that if for any reason the gauge plug should not enter the bore of the ring, the entire head, including the gauge plug, may rock about the pivot axis 224 and thus avoid possible injury to the gauge plug or other parts. An adjustable stop 234 may be provided for limiting the rocking movement of the head 223 so as properly to position the gauge plug for reception in the bore of the ring when the gauge plug is lowered for gauging. As was heretofore stated in connection with the drive of the spindles, the gauging may be performed either while the work-piece is in rotation or after it has been stopped.

As stated, the work-piece is gauged principally for the purpose of making an automatic change in the grinding operation on a piece being ground or to be ground, so as to compensate for errors appearing in the ground piece. Such a control method tends to maintain all of the work pieces within the predetermined tolerance limits. In the particular form illustrated, the gauging determination affects the grinding operation by causing the grinding wheel or wheels to make more or less grinding passes, depending upon whether the piece being gauged is over or under size (but still within the tolerance limits).

A so-called counter mechanism is influenced by the gauging determination to cause the grinding wheel to make more or fewer grinding passes. In the form illustrated (Figs. 26, 19), compressed air is supplied through a conduit 235 and a pressure-reducing unit 236, which latter assures a constant supply of air of uniform low pressure in the conduit 237. The low-pressure air from conduit 237 may discharge into a pressure chamber, such as a diaphragm chamber 238, through a master orifice or bleed valve 239. The orifice or bleed may be adjusted in the usual manner by rotating a valve stem or the like 240. Pneumatically connected with the pressure actuated control device is a conduit 241 leading to the gauge plug as by means of a passage 242 (Fig. 6) in the gauge actuator 226, flexible connection 243, and air passage 244 in the plug mounting. The air bleeding to the pressure-actuated device passes to the gauge plug; and, if the bore of the ground ring is too large, the air escapes about the gauge plug at a relatively rapid rate, and air pressure on the pressure-actuated device builds up only slightly. It will be understood that if the ground bore in the ring being gauged is too small, the air passage between the plug and the bore will restrict the flow of air, and the pressure on the pressure-actuated device will build up to a greater extent.

The pressure-actuated device (in this case the diaphragm 245) is connected to a member, such as a bar 246, which, as will be described, controls the grinding operation within limits.

The grinding operation is varied, as stated, in accordance with a gauging determination, and, in the preferred form, by varying the number of grinding passes through the medium of a so-called counter mechanism. In the particular form illustrated, this counter mechanism includes a mounting plate 247 preferably in the base of the machine (Fig. 5). This plate (Figs. 19 and 20) carries a ratchet counter disk 248 provided with ratchet teeth, as illustrated. The ratchet is advanced by a pawl 249 carried by a crank arm 250 on a shaft 251. The shaft 251 is urged in one direction, as by means of a coil spring 252, so as always to urge the pawl 219 in a direction to cause it to ride up on the shroud 253. The shroud 253 is adjustably mounted on the plate 247 so as to make it possible to vary the point at which the pawl 249 engages with the ratchet wheel, and thus to vary the number of teeth fed. The shaft 251 for actuating the pawl crank 250 is rocked in accordance with the reciprocation of the grinding head. As illustrated, the shaft 251 has a crank 254 (Figs. 3, 5), connected as by means of a link 255 to a reciprocating part such as the lever 117 (Fig. 7). The link 255 is preferably slotted so that during the rocking of the lever 117, particularly when the grinding head 7 is in raised position, the roll or pin 256 may move upwardly in the slot without affecting the crank 254; but, when the roll 256 moves downwardly, it engages an adjustable stop member 257 so as to draw the link downwardly (Fig. 7) and thus rock the shaft 251 to swing the crank 250 and cause the pawl 249 to drop down from the shroud 253 and engage one of the teeth on the counter ratchet wheel 248. Ordinarily, the shroud 253 would be so adjusted as to cause the pawl 249 to advance the ratchet wheel by one tooth for each complete reciprocation of the grinding head. Pawl 258 (Fig. 19) cooperates with the counter pawl 249 to hold the ratchet, as will be understood.

The rotation of the counter ratchet 248, in cooperation with the fluid-pressure-actuated means controlled by the gauge determination, determines the point at which the grinding operation is terminated. In the form illustrated the counter ratchet 248 is provided with a plurality of holes 259 for receiving a tripping peg or abutment 260. These holes are numbered in Fig. 19 to indicate the approximate number of ratchet teeth that will be fed before the grinding operation is terminated. For example, with the peg 260 in the hole marked "50," there will be fifty grinding passes before the grinding operation for the particular piece being ground is terminated.

During the reciprocation of the grinding head the counter ratchet 248 will be rotated by the pawl 249, and, when the peg 260 reaches a position to engage the finger 261, the peg will rock the finger 261 about its pivot 262, for a purpose to be described. The finger 261 is preferably mounted on a lever 263 in such manner that it may be adjusted, as by the screws 264, to compensate for slight inaccuracies in the positioning of the peg and other parts of the mechanism. The lever 263 is carried by the pivot pin 262 movable with the bar 246. A compression spring 265 is mounted between the head 266 connected to the bar 246, and an adjustable screw 267 on the base plate. As heretofore stated, the bar 246 is moved longitudinally by the diaphragm 245, and the position of the latter is, of course, determined by the air pressure in the chamber 238 acting in opposition to the compression spring 265. The head 266 carrying the pivot pin 262, together with the lever 263 and finger 261, is guided in its reciprocable movement as by a guide pin 268, and its left-hand movement, as urged by the spring 265, is limited to an adjustable stop 269.

When the finger 261 (in whatever position it may have assumed) is engaged by the peg 260 on the ratchet wheel, the lever 263 will be rocked, so as to close the switch 4. The closing of the switch 4 (Figs. 19 and 28) closes a relay circuit for energizing the solenoid 2, which withdraws the holding pawl 258. The feeding pawl 249 rides up on the shroud 253 when the lever 250 is rocked by the spring 252 after release of the reciprocating mechanism. When the counter ratchet 248 is released, it is returned to its starting position by means such as a clock spring 270 and comes up against a stop (not shown).

The closing of switch 4 by rocking the finger 261 and lever 263 serves to release the locking pin 123 (Fig. 8), which thereafter renders the grinding-head-reciprocating mechanism inoperative. The grinding head then moves upwardly toward its rest or inoperative position. At about the same time, the same motion which withdrew the locking pin 123 also engages the main cam clutch 109 (Figs. 5 and 8) and puts the cam shaft in rotation. The rotation of the cam shaft, as will be remembered, removes the gauge plug from the work, unlocks the turret, indexes the same, again locks the turret in indexed position and resets the plug gauge before the clutch is disengaged.

The closing of the switch 4 actuates other electrical devices, as will be later described, in connection with the operation of the machine, for shutting down the entire machine if the piece gauged is beyond the limits of tolerance. Means, such as lights or other signals, may also be provided for indicating whether the upper or lower tolerance has been exceeded. In addition closing switch 4 acts to energize the solenoid 1a for clamping the bar 246 in position so that it will be held in that position even after the gauge plug has been removed from the work—all for a purpose to be described in connection with the operation.

Wheel dressers

In the preferred form, the grinding wheels are dressed each time a piece of work is ground. The amount of wheel worn off during the grinding may be disregarded, since an increment is dressed from the wheel each time a piece is ground and the grinding operation always starts with the cutting surface of the wheel in definite position. In the form illustrated, we employ a diamond, or dressing tool of equivalent relative hardness, for each wheel; and this diamond is accurately positioned so as to dress the surface of the wheel and always present a dressed surface in the same relative position of the machine. The dressing mechanism is furthermore preferably arranged so as to be retracted during the grinding operation to an out-of-the-way position. Just before the wheels are to be dressed, the dressers are moved into their operative positions. For dressing new wheels, means may be provided for manually moving the dressing tools relatively to the wheels.

In the form illustrated (Figs. 1, 2, 3, 24), there is a dressing-tool head 271, which is mounted for slidable movement on a pair of guide columns 272—272 mounted in a part of the frame 5. The head 271 has a pair of wheel-dresser arms 273 hingedly mounted thereon and preferably on cone-shaped bearings such as 274. The corresponding hinge-pintle parts are urged toward each other by means of a spring 275, whereby the concentricity of the hinged mounting will be maintained despite slight wear. We provide a tool-dresser arm 273 for each of the grinding stations. The parts shown in Fig. 24 are those relating to the finish grinding wheel. Each tool-dresser arm carries a tool dresser, such as a diamond point 276 (Fig. 25), located, when in operative position, so as to engage the surface of the grinding wheel 95 to dress the surface thereof. Each hinge arm 273 has an ear 277 thereon to engage an adjustable stop 278 on a slidable adjusting plate 279. The slidable adjusting plate 279 is normally held in fixed position on the dressing head 271 so that, when the ears 277 engage the adjustable stops 278 after proper adjustment, the dresser points will be in proper position to dress the wheels.

In order to retract the wheel dressers to an out-of-the-way position during the grinding operation, we may provide links 280—280 pivotally secured, respectively, at 281 to crank portions on the dresser arms 273. These links are pivotally connected at 282 to one arm of a crank 283 pivotally mounted at 284 on the dresser head 271. The opposite end of the crank 283 is pivotally connected as by a universal joint 285 to a link 286. The link 286 is pivotally connected as by a universal joint 287 to a crank 288 mounted on a shaft 289 which extends into the base of the machine. The shaft 289 is oscillated by means of a crank 290 carrying a roller for engagement with the cam 291 on the main cam shaft 12 of the machine.

It will be seen that when the shaft 289 is rocked in one direction, the two links 280 connected to the dresser arms will be pulled so as to cause the heads 292 on the links 280 positively to swing the dresser arms about their hinge pintles and positively to withdraw the wheel dressers to an out-of-the-way position where they will in nowise interfere with the reciprocating portions of the grinding head during the grinding operation. When the shaft 289 is oscillated in the opposite direction, the links 280, through the medium of the springs 293, rock the dresser arms and resiliently hold the same to make the ears 277 engage with the adjusting screws 278. When the arms are in the resiliently rocked position, the wheel dressers are in proper position to dress the wheels.

It will be seen that the adjusting screws 278 serve to adjust the dresser arms 273 relatively to each other, as well as to the machine as a whole. Normally, after the adjustments of the adjusting screws 278 have once been made, such adjustment need not be changed. We have provided means for adjusting the positions of both dresser arms simultaneously and very accurately. As has been stated, the adjusting screws 278 are mounted in an adjusting plate 279 slidable on the dresser head 271. The adjusting plate 279 may be provided with an ear 294 through which an adjusting screw 295 may pass. Means, such as lock nuts 296, may serve to hold the screw 95 against rotation or longitudinal motion relatively to the adjusting slide 279. The adjusting screw 295 is threaded into a boss 297 of the hand adjusting wheel 298. The boss 297 is threaded as indicated at 299 in a bore in the dresser head 271. It will be seen that the hand wheel 298, due to its threaded connection with the dresser head 271 and due to the threaded connection between the hand wheel and the screw 295, will constitute a differential-screw adjustment which may be employed for moving the adjusting slide 279 with great accuracy. A detent such as a spring 300 may be employed for holding the hand wheel 298 against accidental movement.

Normally, the grinding wheels are dressed by being moved past the dressing tools during a regular part of the cycle of the machine. However, we have provided means for manually moving the dressing tools and wheels relatively to each other. In the form shown, the dresser head 271, which, as heretofore stated, is slidably guided on the two columns 272, may be provided with a cross bar 301 to which is secured a head 302 pivotally connected at 303 to a lifting link 304. The link is pivotally connected at 305 to a disk crank 306, carried on a shaft 307, which in turn is mounted in a bridge head 308 fixedly mounted at the tops of the columns 272. The dresser head is held in its lowermost normal position, as shown in Fig. 24, as by means of a coil spring 309 engageable with both the bridging head 308 and the hand wheel 310, which is secured to the shaft 307. When it is desired to hand dress the grinding wheels, the hand wheel 310 is turned so as to cause the crank 306 to raise the dresser head bodily and to cause the dresser points to traverse the surfaces of the grinding wheels. The spring 309 will always return the dresser head to its lowermost normal position as soon as the hand wheel is released.

If desired, a part of the bridging head 308 may be provided with an oil distribution means or manifold 311 to which oil may be conducted and from which oil may be conducted to various parts of the machine.

A lubricator 332 of any desired type may be employed for lubricating various parts of the machine, and the pump or agitator means associated with this lubricator may be driven by the cam shaft, as will be understood.

General operation

The general operation of the grinding machine as herein disclosed is as follows:

The main drive and coolant-pump motors are started and the air turned on. We shall assume that a work piece, such as a ball bearing ring 32 to be bore ground, is mounted in the chuck at the loading station. The turret is indexed to carry the loaded work piece and subsequently-loaded work pieces in seriatim to the rough-grinding station, the finish-grinding station and the gauging station; and we shall assume that there is a finish ground piece in the gauging station and pieces being both rough ground and finish ground. We shall further assume the parts to be in position immediately to start the grinding operation; that is to say, the operative drive parts are in the position shown in Fig. 5. The clutch for the main cam shaft has been disengaged and the latter remains stationary during the grinding operation. In addition the tapered head locking pin 123 will be in its "in" position, as shown in Fig. 5. The eccentric 114 will reciprocate the grinding head through the reciprocation linkage, shown particularly in Fig.

7, and the entire grinder head 7 will be oscillated up and down to grind the rotating work pieces.

During each reciprocation of the grinding head the cams 173—174 (Figs. 3, 15) will oscillate the lever 175 and cause the feed ratchet 154 to advance, say, one tooth for each reciprocation. Such advancement of the feed ratchet 154 will rock the feed arms 153—199 (Fig. 16) and cause the grinding wheels to be fed into the work, as has been heretofore described. The grinding proceeds and for each reciprocation of the grinding head the counter ratchet 247 (Fig. 19) will be advanced.

It may have been determined that for the particular work pieces being ground fifty passes will be required, and therefore the tripping peg 260 will have been set in the "50" hole in the counter ratchet 247. The trip finger 261 will be positioned in accordance with the gauging operation, which determines the position of the diaphragm 245 (Figs. 19, 26). If the piece being gauged is of the exact size desired, the trip finger 261 will be so positioned that it will be rocked by the trip peg 260 when the reciprocating head has made fifty passes. However, if the piece being gauged has been ground too much, then the diaphragm will be in a more or less left-hand position as shown in Fig. 19, and the trip finger 261 will be in a corresponding left-hand position, so that the tripping peg in the fifty hole will engage and rock the trip finger 261 before the reciprocating head has made fifty passes. It will be understood that, if the piece being gauged is under-sized, the escape of air from the gauging head will be restricted, pressure in the chamber 238 will be increased, and the diaphragm 245 moved to a more or less right-hand position. As a result, the trip peg in the fifty hole will not reach the trip finger 261 to trip the same until the reciprocating head has made more than fifty grinding passes. It will be seen, therefore, that the size of the last piece ground will determine the extent of the next grinding operation. In this way errors in grinding will be compensated for, and all pieces will normally be ground to uniform size within the tolerance limits.

When the grinding operation is complete, as determined by the position of the trip finger (Fig. 19), the trip finger 261 and with it the lever 263 is rocked, so as to close the switch 4, as heretofore noted. As has been described, closing of the switch 4 causes the solenoid 2 (Figs. 19, 28) to be energized so as to retract the holding pawl 258; and, as soon as the locking pin 123 is forced from its seat into the position shown in Fig. 8, the counter-pawl-actuating shaft 251 will be rocked by the spring 252 to force the pawl 249 up on its shroud 253. As soon as the counter ratchet 247 is released from the two pawls, the clock spring 270 immediately rotates the former back to its initial position against a stop (not shown).

Other mechanisms are also set in motion when the finger 261 trips to close the switch 4. When the switch 4 is closed as stated, a relay operates to reverse the solenoid valves 312—313 (Figs. 26, 28); and air pressure from the main air supply 314 passes through solenoid valve 313, thence through pipe 315 into the head end of cylinder 316. Upon opening of the solenoid valve 313 the solenoid valve 312 is closed; it being understood that, while the solenoid valve 313 is closed, the solenoid valve 312 is open, so that the head end of the cylinder 316 is normally opened to exhaust. Upon the admission of compressed air to the head end of the cylinder 316 the differential piston 317 (Fig. 5) is forced upwardly (against the air pressure constantly on the tail end) and, through the linkage heretofore described, rocks the lever 136 to withdraw the locking pin 123 and thus release the reciprocating linkage to the grinding head. Raising of the differential piston 317 also acts through the link 141 to rock the lever 145 and engage the clutch of the main cam shaft 12. The springs 144 on the link 141 are merely for the purpose of preventing jamming of the parts. The cam shaft is then started in operation. At the same time that the solenoid valves 312—313 are reversed, compressed air enters through branch pipe 318 to the head end of the differential piston 203 (Figs. 15, 26) through passage 319. Simultaneously, air entering through passage 320 acts on the head of air piston 196 (Fig. 15) so as to rock the shrouds 187—188 and release the feed pawls 182—184 of the feed mechanism. As soon as the feed pawls are released, differential piston 203, moving forward (against the air pressure constantly on the tail end), causes the pawl finger 213 to engage a tooth on the retracting gear 212 to rotate the latter and, consequently, to rotate the meshing pinion and feed ratchet 154 back by an amount slightly less than the amount which the ratchet 154 was fed forward. The pawl nose 213 retracts the feed ratchet 154 an amount less than the ratchet was fed forward, because the pawl nose may ride on top of a tooth on retracting gear 212 and drop into the next space to engage a tooth. The difference between the amount fed and the amount retracted (disregarding wear) is subsequently removed by the wheel dressers.

When cam shaft clutch 108 is engaged, the cam shaft 12 starts to rotate, and cam 228 begins to rock the lever 229 to withdraw the plug gauge from the ground piece in the gauging station (Figs. 6 and 27). At the same time, the switch 1 (Figs. 5, 28) is closed to energize the solenoids 1A and 1. When solenoid 1A is energized, the iron plate 321 (Figs. 19, 22), fastened to the rod 246, is held stationary to fix the rod 246 against action of the spring 265. If the bar 246 were not held stationary by some means, it would immediately be shifted to the left when the plug gauge is removed from the work. While the bar 246 is being held stationary, the solenoid 1 (Figs. 19, 21) is picked up and, through linkage 322, swings the two switches 1A—1B about their pivot mounting 323. The bar 246 carries an abutment 324 positioned above the switch contact arms 325—326. If this abutment is positioned between the arms 325—326, as when the gauged piece is within the tolerances and consequently the diaphragm 245 is, say, slightly to the right of the position shown, neither of the switches 1A—1B will be closed. However, if the gauged piece has been ground too much, the abutment 324 will be in a left-hand position, say where it is now positioned in Fig. 19; and the arm 325 will be engaged to close switch 1A. On the other hand, if the gauged piece is too small, the abutment 324 will be located in a right-hand position so as to engage the arm 326 and close the switch 1B.

Closing of either switch 1A or 1B acts to break the holding circuit and throw out the main motor contactor, represented conventionally at 327 (Fig. 28). At the same time, by similar conventional switch mechanism, designated generally 328, the coolant-pump motor circuit is broken. Signal

lights or equivalent devices 329—330 are provided in the circuits so that it may be determined by, say, the color of the lights whether the ground piece being gauged is too large or too small; and the operator is afforded an opportunity to make whatever adjustments or corrections may be necessary for proper grinding within the tolerance limits. As stated, if the abutment 324 happens to be located between the arms 325—326 when the switches 1A—1B are picked up, nothing will occur to disturb the motor circuits and the machine will continue to function normally.

Upon rotation of the cam shaft 12, the cam 291 (Fig. 5) rocks the arm 290 and shaft 289 to move the wheel dressers (Figs. 1 and 24) into dressing position. After the wheel dressers are so positioned, the cam 152 on the cam drum (Figs. 3, 5) rocks the arm 149 and through the rod 148 restrains the upward movement of the dressing head under the influence of the lifting spring 130, so that the grinding wheels are moved past the dressing tools slowly as the wheels are dressed. In the meantime, the locking lever 68 has been rocked to release the turret; and the latter is then indexed to bring a new piece to the rough-grinding station, to transfer a rough-ground piece to the finish-grinding station, and to transfer a finish-ground piece to the gauging station. At or near the end of the turret indexing movement, the cam 152, acting on the lever 149, starts to move the grinding head downwardly so as again to cause the grinding wheels slowly to pass the dressers for a finish dressing. As soon as the wheels have been dressed, the dressers are again swung to an out-of-the-way position by the cam acting on arm 290, and the grinding head continues to move down to about its uppermost position of reciprocation. When indexing is complete, the plug gauge is again moved down into gauging position by a rocking of lever 229.

Before the next grinding operation, the switch 3 is closed by rotation of the cam shaft. This action of switch 3, in cooperation with a relay, deenergizes solenoid 2 and permits the holding pawl 258, acting on the counter ratchet 247 (Fig. 19), to fall into place.

A short while thereafter, switch 2 (Figs. 5, 28) is closed by rotation of the cam shaft; and since this switch is in series with switch 2A, which is actuated by an angularly adjustable cam 331 on the constantly rotating shaft 113, the circuit to be controlled is not energized until both switches are operating together. Switch 2A, because of its easy location for adjustment and its operation directly from the main drive, acts in effect as a vernier for the cam-shaft-actuated switch 2. Simultaneous closing of the switches 2—2A completes circuits to reverse the solenoid valves 312—313 so as to open the head ends of the cylinders 316 and 205 to exhaust and to permit the compressed air, which is always acting on the tail ends of those cylinders, to retract the pistons 317 and 203. Retraction of the piston 317 urges the main cam shaft clutch 109 toward disengaged position, and as soon as the single tooth 110 on the clutch spool arrives opposite the notch 111, the cam shaft clutch will be thrown out. It will be understood that spring 144 permits actuation of the rod 141 by the piston 317 before the tooth 147 comes opposite its notch. Since the cam 152 has lowered the grinding head and reset the linkage to about the position shown in Fig. 7, the taper head locking pin 123 easily finds its seat when the lever 136 is rocked by the piston 317 in its retraction. It will be understood that adjustment of the cam 331 may so be made as to cause the vernier switch 2A to reverse the solenoid valves and to actuate piston 317 at the instant when the seat 124 is opposite the locking pin 123.

The shifting of the solenoid valves also opens the head end of the cylinder for plug piston 196 to exhaust, and spring 194 immediately raises the linkage 193 to lower the shrouds 187—188 of the feed mechanism (Fig. 15) to permit the feed pawls to fall into operative positions.

After the solenoid-valve reversal has operated all pistons (317, 303, and 196), the grinding head proceeds to reciprocate and to grind the work pieces as heretofore described. At the same time, the counter-means mechanism operates; and, if the piece being gauged is within the tolerances, the grinding operation is stopped normally by the counter-peg 260 acting against the finger 261 in normal position. If the gauged piece is not within the tolerance limits, the machine will be stopped; and, if the gauged piece is within tolerance limits, but still over or under size, the finger 261 will be automatically positioned so as to cause one less grinding pass or one more grinding pass—in this way any tolerable errors in the gauged piece will be compensated for in the pieces being ground.

We have provided means for permitting continuous automatic operation of the grinder and have disclosed various safety and signal devices to guard against or indicate errors and to prevent wastage of material which might occur from turning out of work either above or below tolerance limits.

While the invention has been described in considerable detail and a preferred form illustrated, it is to be understood that various changes may be made within the scope of the invention as defined in the appended claims. The invention in its broader aspects includes certain sub-combinations which may be used independently of other portions of the invention.

We claim:

1. In an automatic grinding machine, grinding means, means for traversing said grinding means and work piece relatively to each other for grinding the latter, adjustable means to be set to cause said traversing means to normally make a definite number of grinding passes, gauging means for ground work, and means controlled by said gauging means for varying the setting of said adjustable means for causing said traversing means to make a different number of grinding passes.

2. In a grinding machine, grinding means for grinding work pieces seriatim, adjustable means to be set to cause said traversing means to transverse said grinding means and a work piece relatively to each other normally for a definite number of grinding passes, gauging means for a ground work piece, and means controlled by said gauging means for controlling said adjustable means to cause said traversing means to traverse said grinding means and work piece a different number of grinding passes.

3. In a grinding machine, a grinding wheel, a work piece carrier, means for indexing said grinding wheel and work piece carrier relatively to each other to cause a work piece to be moved relatively to said grinding wheel from a grinding station to a gauging station, means for traversing said grinding wheel and a work piece being

ground, control means to be set to cause said traversing means to cause said grinding wheel and work piece to normally make a definite number of grinding passes, work gauging means for gauging a ground work piece in gauging station, and means controlled by said gauging means for acting on said control means to cause said traversing means to make a different number of grinding passes in accordance with a gauging determination on the ground work piece.

4. In a grinding machine, a grinding wheel for grinding work pieces, means for traversing said grinding wheel and a work piece relatively to each other, manually settable means to be set for causing said traversing means to traverse said work piece and grinding means a normally definite number of grinding passes, gauging means for a work piece, and means controlled by said gauging means to act on said settable means to cause said traversing means to make a different number of grinding passes.

5. In a grinding machine, a base, an upright hollow column thereon, a grinding head mounted for reciprocation on said column, spring means for moving said grinding head to its extreme upper position on said column, reciprocating means including means extending downwardly through said column for reciprocating said grinding head, grinding means carried by said grinding head, gauging means carried by said base, an indexible turret mounted for rotation about said column, a plurality of work holding chucks carried by said turret and indexible therewith so as to carry work pieces from said grinding means to said gauging means, means for rotating said chucks, and means controlled by said gauging means for controlling the action of said grinding means.

6. In a grinding machine, a grinding head, resilient means for constantly urging said grinding head toward retracted position, reciprocating means for moving said head against the action of said resilient means, means for disengaging said reciprocating means and said grinding head, and means for restraining the movement of said grinding head under the influence of said resilient means when said reciprocating means is disengaged from said grinding head.

7. In a grinding machine, a grinding head, a grinding wheel rotatably carried thereby, means for reciprocating said grinding head and a work piece relatively to each other, means for disconnecting said reciprocating means, wheel-dresser means, and operative means for moving said wheel-dresser means and said grinding wheel past each other for dressing the latter after disconnection of said reciprocating means, said operative means being constructed and arranged to move said wheel-dresser means and grinding head relatively to each other at a rate slower than when reciprocating.

8. In a grinding machine, a grinding means, means including counter means to be set to cause said grinding means to make a normal predetermined number of grinding passes, gauging means for a ground work piece, and means controlled by said gauging means for varying the action of said counter means to cause the grinding means to make a number of grinding passes differing from said predetermined normal number.

9. In a grinding machine, a grinding head, resilient means for constantly urging said grinding head in one direction, reciprocating means for reciprocating said grinding head in the opposite direction, said reciprocating means including a lever, a fulcrum member for said lever, and means for detachably holding said fulcrum on a fixed part, whereby upon release of said fulcrum from said fixed part said grinding head may be moved by the action of said resilient means.

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