June 27, 1950 M. H. ARMS ET AL 2,513,228

NOZZLE GRINDING MACHINE

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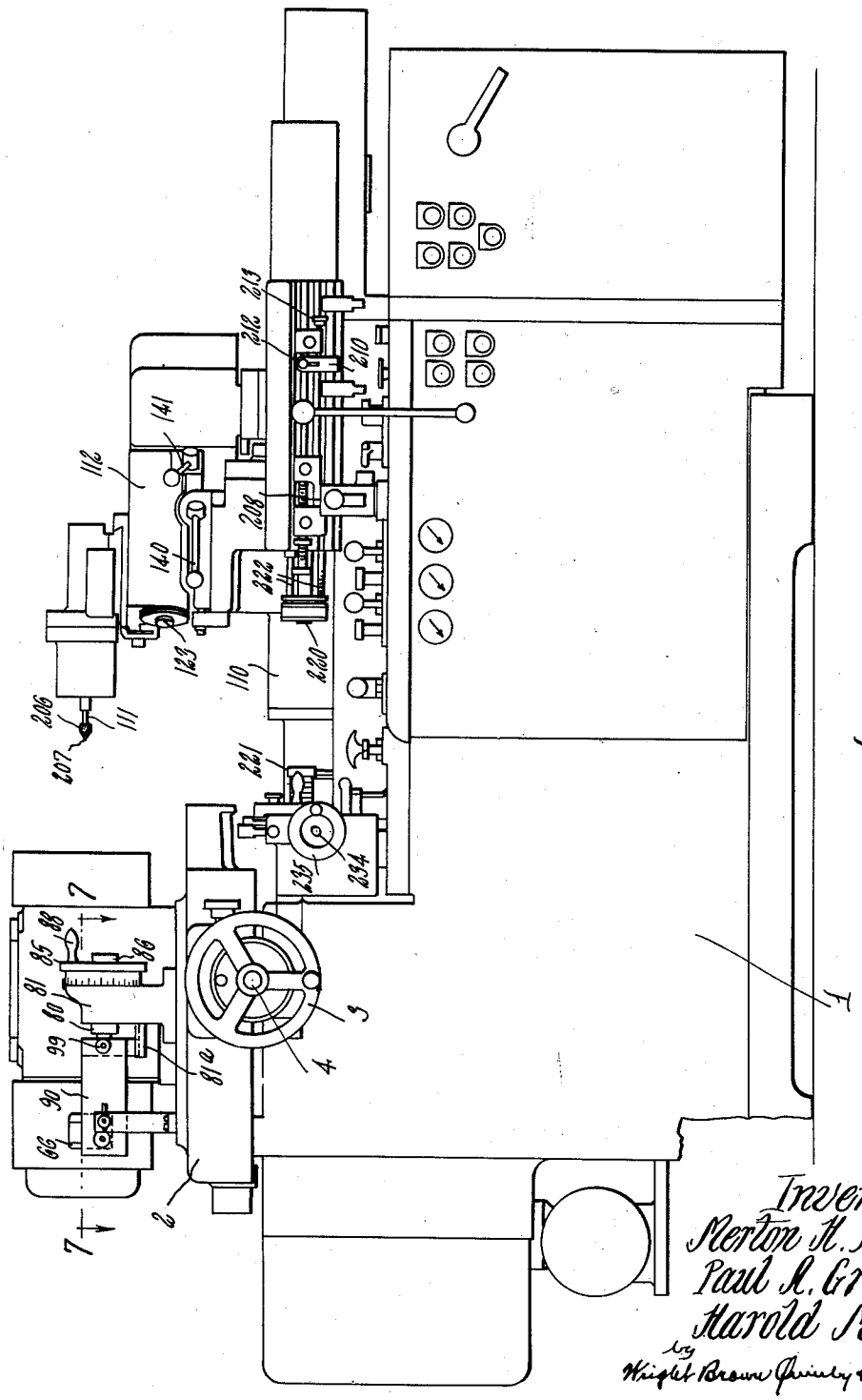


Fig. 1.

Inventors
Merton H. Arms
Paul M. Grobey
Harold M. Day
by
Wright Brown Quinby & May.
Attys.

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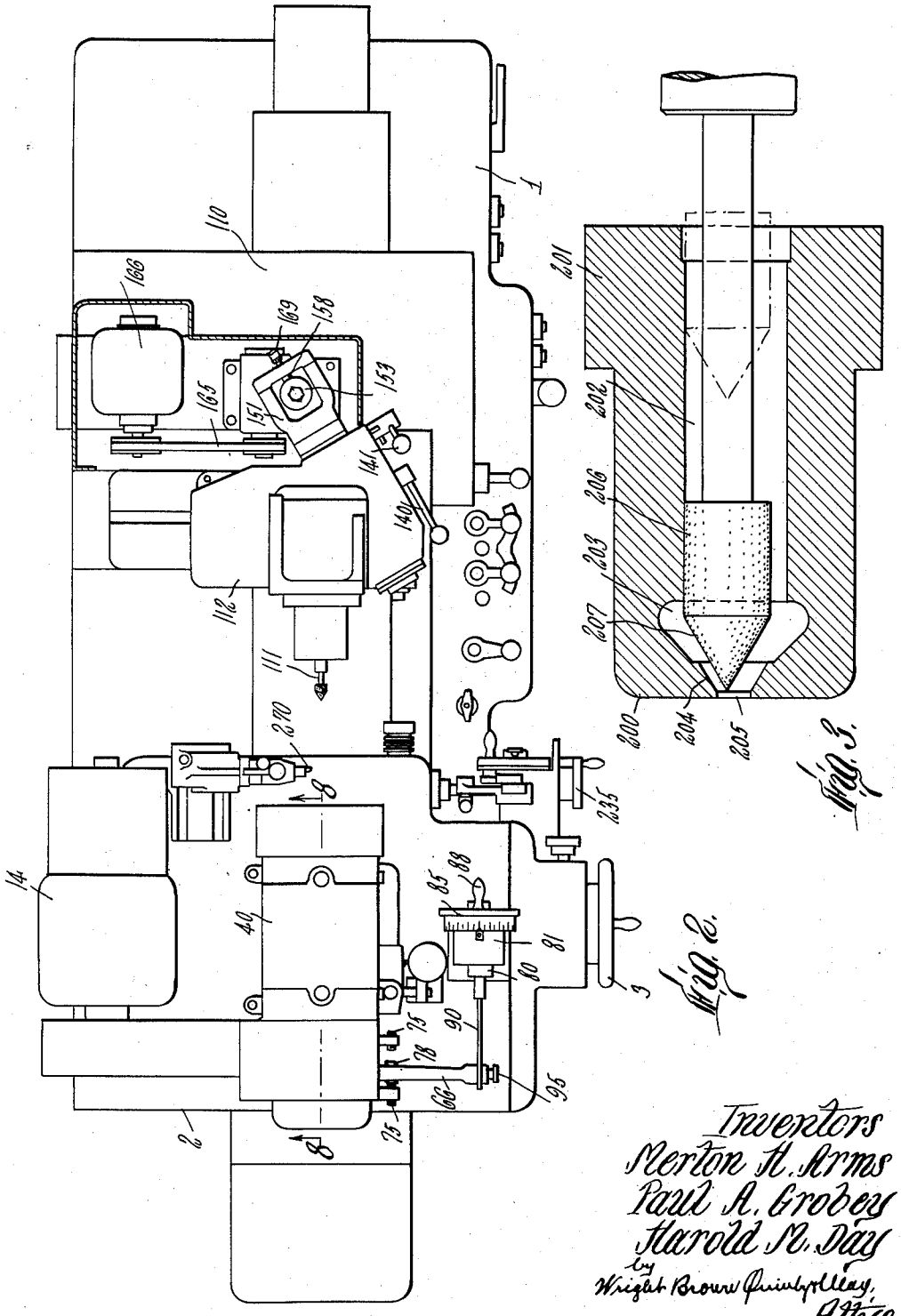


Fig. 3.

Fig. 2.

Inventors
Merton H. Arms
Paul A. Grobey
Harold M. Day
by
Wright Brown Quinby & Clay,
Attys.

June 27, 1950 M. H. ARMS ET AL 2,513,228

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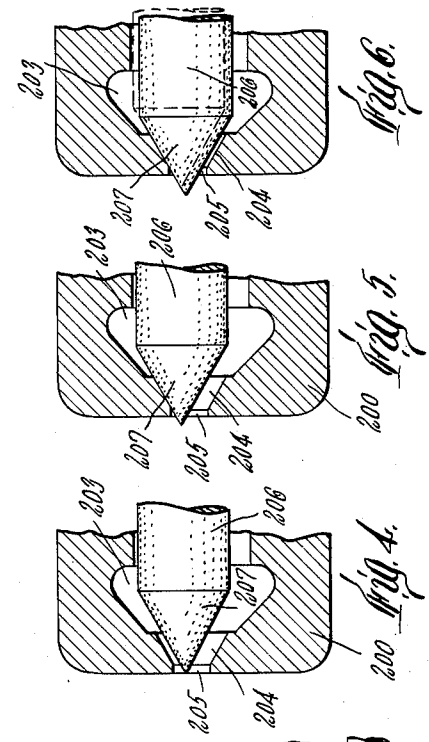


Fig. 6.

Fig. 5.

Fig. 4.

Fig. 7.

Inventors
Merton H. Arms
Paul A. Grobey
Harold M. Day
by
Wright Brown Quinby & Clay,
Attys.

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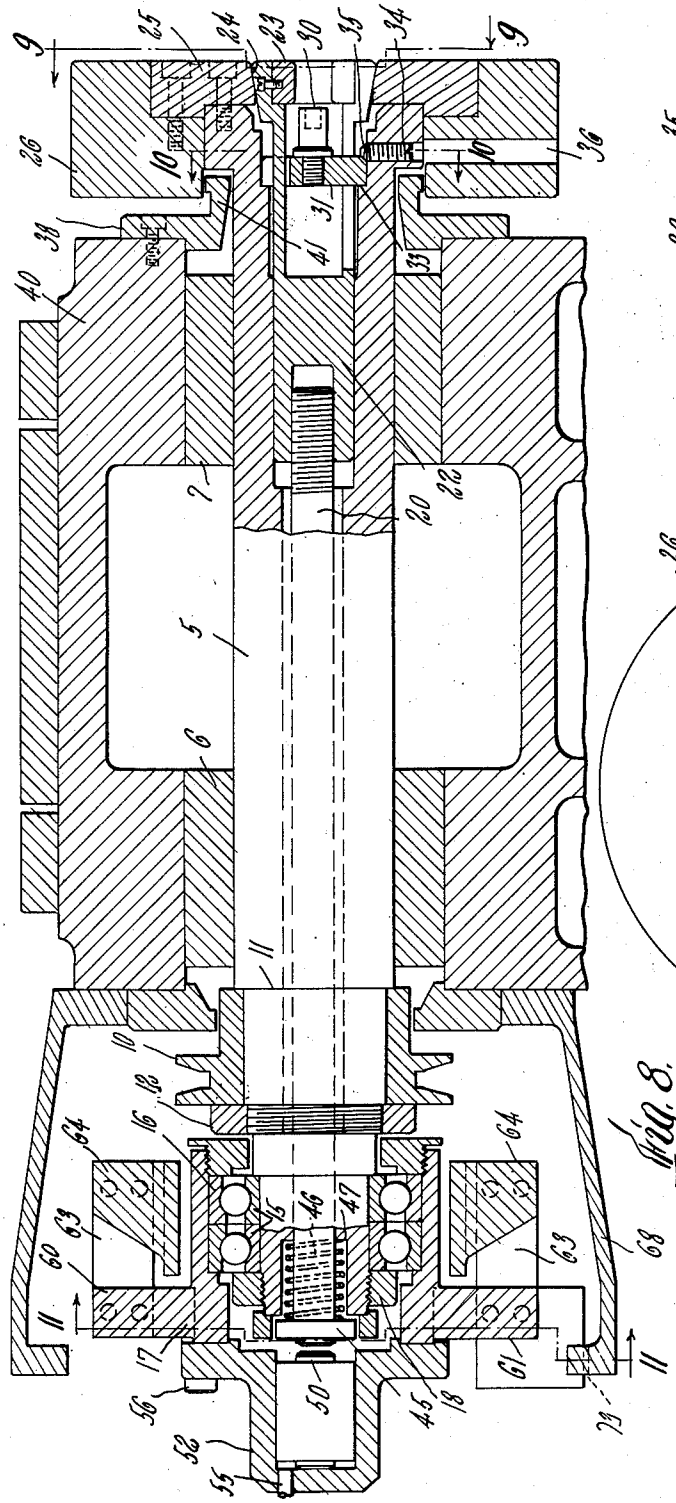


Fig. 8.

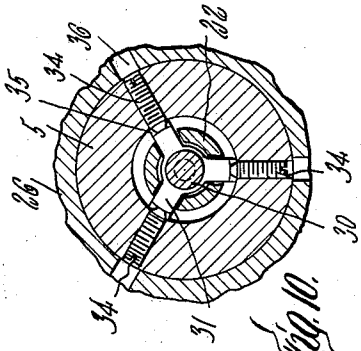


Fig. 10.

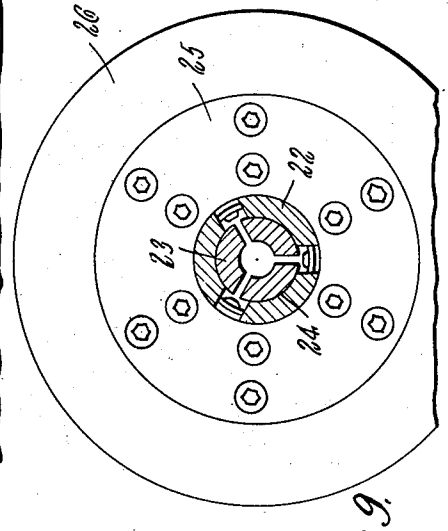


Fig. 9.

Inventors
Merton H. Arms,
Paul A. Grobey
Harold M. Day
by
Wright Brown Quinby & May.
Attys.

June 27, 1950 M. H. ARMS ET AL 2,513,228

NOZZLE GRINDING MACHINE

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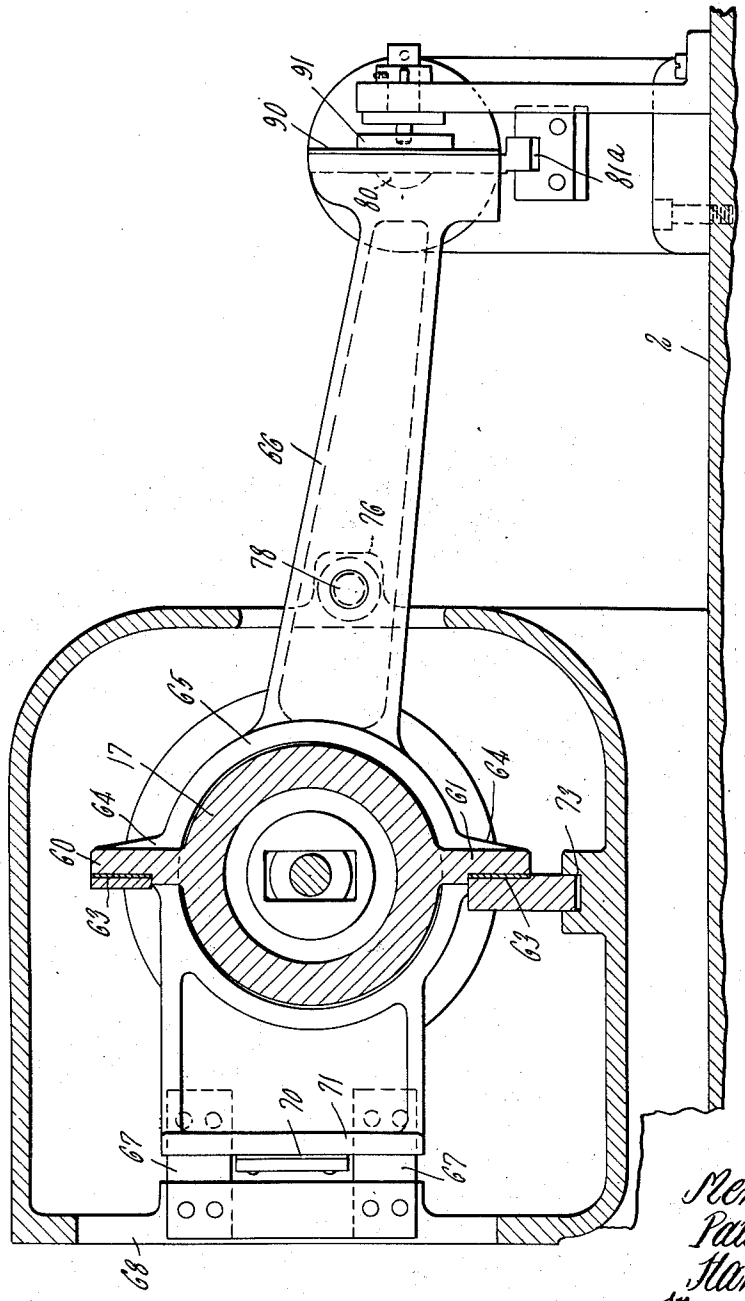


Fig. 11.

Inventors
Merton H. Arms
Paul A. Grobey
Harold M. Day
by
Wright Brown Quinby & May
Attys.

June 27, 1950 M. H. ARMS ET AL 2,513,228

NOZZLE GRINDING MACHINE

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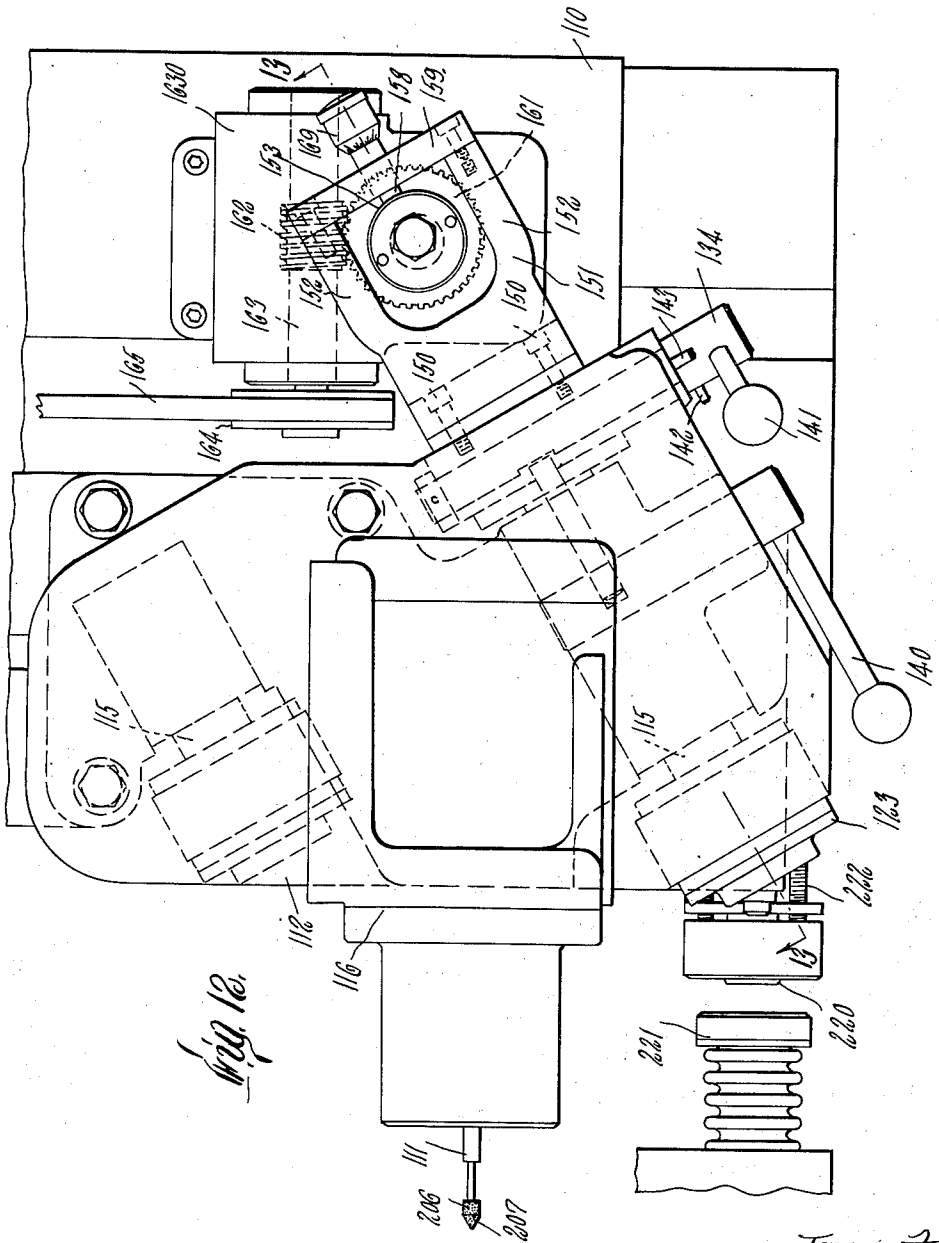


Fig. 12.

Inventors
Merton H. Arms
Paul A. Grobey
Harold M. Day
by
Wright Brown Quinby & May,
Attys.

June 27, 1950 M. H. ARMS ET AL 2,513,228

NOZZLE GRINDING MACHINE

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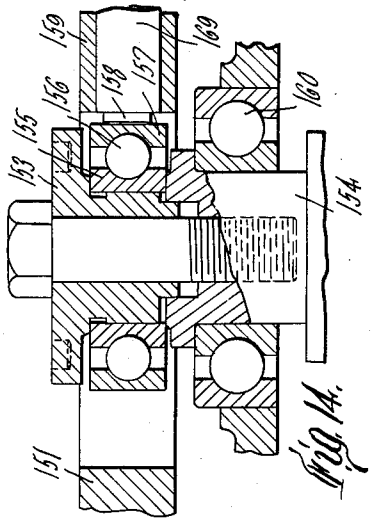


Fig. 14.

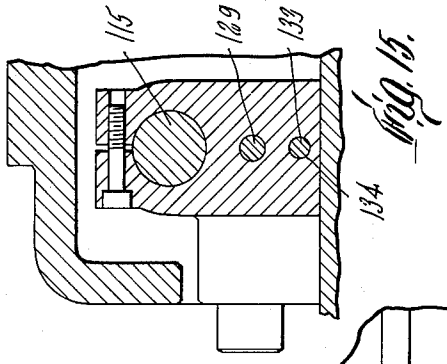


Fig. 15.

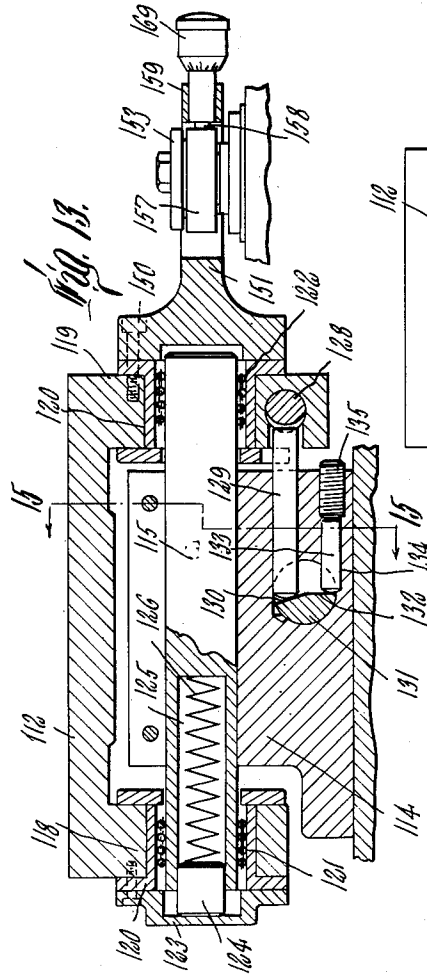


Fig. 13.

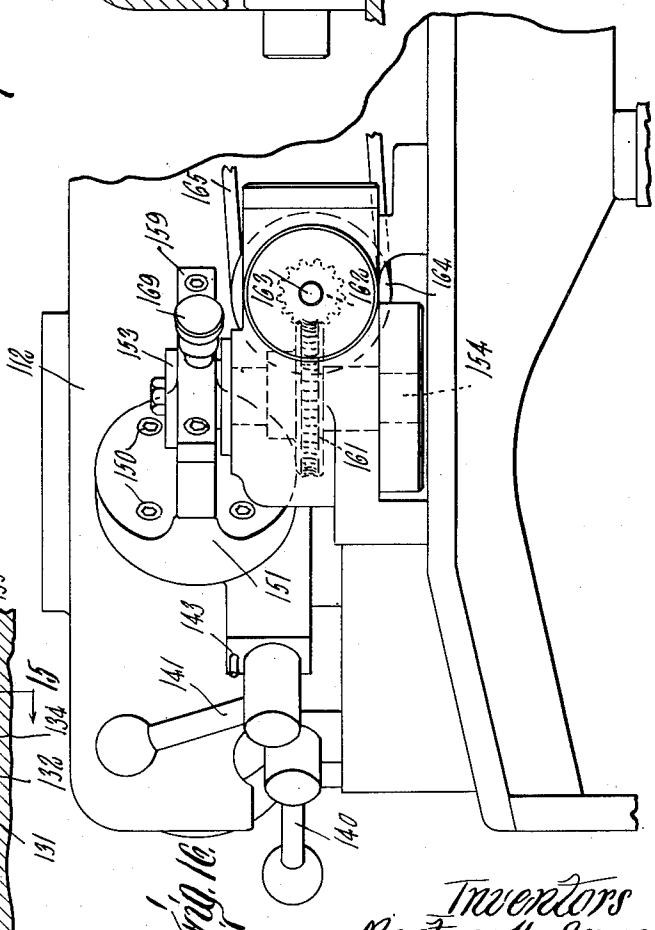


Fig. 16.

Inventors
Merton H. Arms
Paul A. Grobey
Harold N. Day
By Wright Brown Quinby & Clay
Attys.

June 27, 1950 M. H. ARMS ET AL 2,513,228

NOZZLE GRINDING MACHINE

Filed Feb. 25, 1947 8 Sheets-Sheet 8

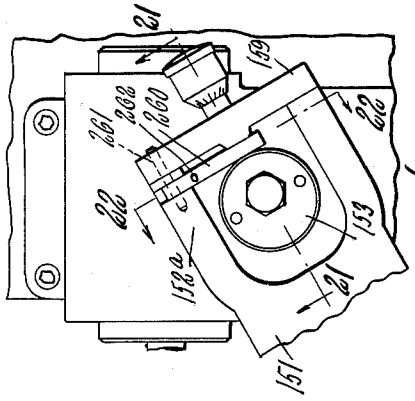


Fig. 20.

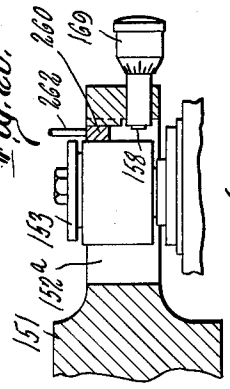


Fig. 21.

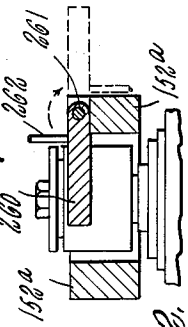


Fig. 22.

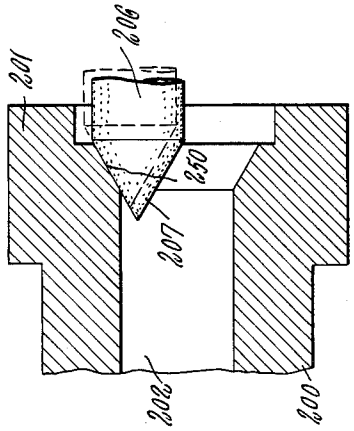


Fig. 19.

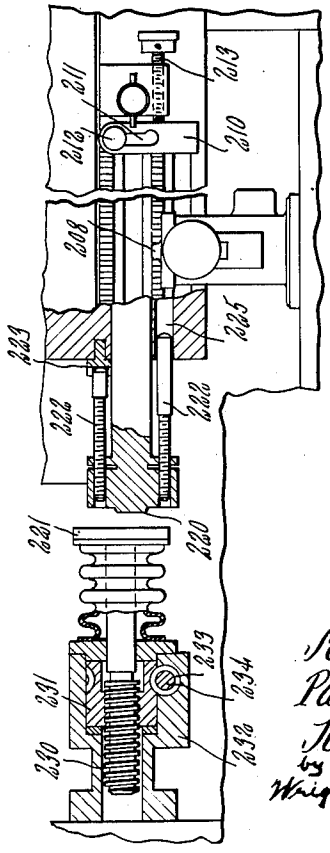


Fig. 18.

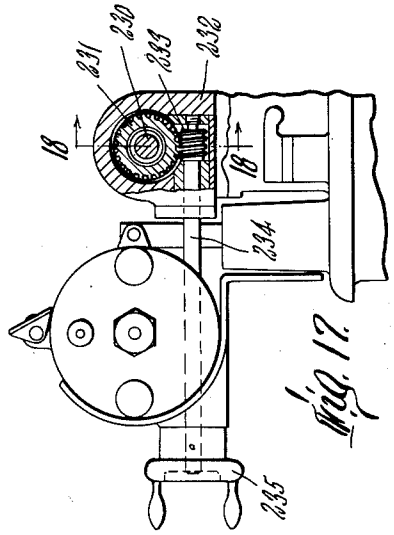


Fig. 17.

Inventors
Merton H. Arms
Paul A. Grobey
Harold M. Day
by Wright Brown Quinby & Clay
Attys.

Patented June 27, 1950 2,513,228

UNITED STATES PATENT OFFICE

2,513,228

NOZZLE GRINDING MACHINE

Merton H. Arms, Paul A. Grobey, and Harold M. Day, Springfield, Vt., assignors to Bryant Chucking Grinder Company, Springfield, Vt., a corporation of Vermont

Application February 25, 1947, Serial No. 730,686

11 Claims. (Cl. 51—50)

1

This invention relates to internal grinding machines and has for an object to provide such a machine capable of grinding the bore of a nozzle having a cylindrical bore for a portion of its length communicating with one or more tapered bores, one of the tapered bores leading to a discharge orifice, the machine being capable of grinding the cylindrical and tapered bores with a single grinding wheel having cylindrical and tapered grinding faces.

A further object of the invention is to provide such a machine capable of grinding a tapered bore leading to an orifice of very small diameter.

A further object is to provide such a machine wherein a pair of tapered bore portions are ground by different portions of the tapered face of the grinding wheel.

Further objects and advantages will appear from a description of an embodiment of the invention shown in the accompanying drawings, in which

Figure 1 is a front elevation of a grinding machine embodying the invention.

Figure 2 is a top plan view of the same.

Figure 3 is a longitudinal central sectional view of a nozzle showing the grinding wheel operating upon the cylindrical bore and showing the traverse limits.

Figures 4, 5 and 6 are views similar to a portion of Figure 3, but showing different relative positions of the work and grinding wheel during different stages of the grinding operation.

Figure 7 is a sectional view on line 7—7 of Figure 1.

Figure 8 is a sectional view on line 8—8 of Figure 2.

Figures 9, 10 and 11 are sectional views on the correspondingly numbered section lines of Figure 8.

Figure 12 is a view similar to a portion of Figure 2, but to a larger scale and showing the wheel head.

Figure 13 is a sectional view on line 13—13 of Figure 12.

Figure 14 is a fragmentary view similar to a portion of Figure 13, but to a larger scale and in further section.

Figure 15 is a detail sectional view on line 15—15 of Figure 13.

Figure 16 is a right hand end elevation of the machine.

Figure 17 is a fragmentary view partly in elevation, and partly broken away and in section, of the facing stop adjusting mechanism.

Figure 18 is a detail sectional view of the facing stop mechanism on the work and wheel heads on line 18—18 of Figure 17.

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Figure 19 is a fragmentary sectional view similar to a portion of Figure 3, but showing a modified form of nozzle and the grinding of a second taper surface therein.

Figure 20 is a fragmentary top plan view similar to a portion of Figure 12, but showing a modification particularly suitable for grinding a nozzle of the form partly shown in Figure 19.

Figures 21 and 22 are detail sectional views on lines 21—21 and 22—22, respectively, of Figure 20.

The drawings illustrate an internal grinding machine of the general type shown in the Arms Patent No. 2,310,338, granted February 9, 1943, for Metal Working Machines, but involving certain changes particularly adapting the machine for grinding the cylindrical and tapered bores of a nozzle such as is used in connection with the fuel injection system of Diesel engines.

The machine comprises a bed 1 carrying thereon at one end, a work carriage 2 mounted for motion from front to back of the machine, this front and back motion being employed to feed and retract the work relative to the grinding wheel when grinding the cylindrical hole in the work. The mounting of this carriage may be the same as that shown in the Arms Patent No. 2,310,338, to which reference has previously been made, and shown herein is a wheel 3 on the forward face of the carriage 2 and fixed to a feed shaft 4, by the rotation of which this motion of the work carriage is produced as fully disclosed in that Arms patent.

Work support

Within the work carriage is journaled a work-carrying spindle 5, but this spindle is mounted in a different manner from the disclosure in the Arms patent in order to provide for axial motion of the spindle relative to the work carriage. This axial motion is for the purpose of feeding the work axially toward the wheel when the taper bore portions of the nozzle are being ground, as will later more fully appear. The spindle 5, as shown best in Figures 7 and 8, is slidably and rotatably mounted in spaced bearings 6 and 7, which may, if desired, be of the type shown in the Arms Patent No. 2,354,296, granted July 25, 1944, for Grinding Machine, and outwardly of the rear bearing 6, it has fixed thereto a belt pulley 10 by which the spindle may be rotated. This belt pulley may be secured in position against an annular shoulder 11 on the spindle by means of a nut 12 threaded on the spindle and engaging the outer face of the pulley. This pulley may carry a suit-

able driving belt (not shown) by which the spindle may be rotated from a motor 14 (Figure 2) carried by the work carriage 2. Outwardly of the pulley 10 the spindle 5 is journaled in radial thrust angular contact ball bearings 15 arranged back to back and loaded by tightening the nut 18. The outer raceways 16 of these ball bearings 15 are carried by a collar 17. The spindle 5 thus rotates without backlash and thus in fixed axial relation thereto within the collar 17 which is held against rotation as will later appear.

The spindle 5 is hollow and carries axially movable therein, a rod 20, the forward end of which is connected to a work-clamping collet 22 having removable jaw clamping pads 23 at its forward end for engagement with the outer face of a work piece consisting of the nozzle to be ground and as shown in Figures 3 or 19. The outer faces of the collet jaws, such jaws being shown at its forward end, are formed with inclined faces 24 with which cooperate mating faces on a ring 25 carried by a face plate 26 which is secured to the forward end of the spindle. The face plate acts as a counterbalance for this end of the spindle for the weight of parts at the other end. The spindle also carries a limit stop 30 to limit the extent to which the work pieces may be inserted between the pads 23. This stop 30 at its rear end is threaded into a spider 31 which extends radially outwardly between the jaws of the collet, as shown best in Figure 10, the outer ends of the spider arms being clamped against an annular shoulder 33 within the spindle 5 as by taper ended screws 34 threaded transversely through the spindle 5, their conical ends engaging tapered faces 35 of the spider arms. The face plate 26 may be provided with holes 36 in line with the screws 34 so that access may be had to these screws from the exterior of the face plate. A dust guard element 38 is attached to the inner face of the bearing support 40 and has a neck portion 41 projecting inside of the rear face of and close to the face plate 26 and relative to which the face plate may be moved axially with the axial motion of the spindle 5.

The rear end of the rod 20 is provided with a head 45 against the forward face of which bears a spring 46 seated in a recess 47 in the outer end of the spindle, this spring tending to hold the rod 20 retracted with the collet in work-clamping position. It may, however, be forced forwardly to release the collet by engagement of a piston abutment 50 against the rear end of the rod 20, the piston being slidable in a fluid pressure cylinder 52 to which fluid under pressure may be admitted or discharged through a pipe 55. This cylinder 52 is held to the collar 17 as by screws 56.

The collar 17 has a pair of diametrically opposed outwardly extending lugs 60 and 61 to which are secured the rear ends of a pair of flexible flat springs or reeds 63, the forward ends of which are secured to a pair of arms 64 projecting from the upper and lower portions of a yoke ring 65 forming part of a lever 66, the rear end of which is fulcrumed on a pair of leaf springs or reeds 67 secured at their rear ends to a frame portion 68 of the work carriage, this portion forming a housing for the rear end of the spindle. A third leaf spring or reed 70 is anchored at one end to the rear upright wall 71 of the lever 66, and at its forward end to a bracket portion 72 of the work carriage, as shown best in Figure 7. This provides a pivotal mounting of the rear end of the lever 66 formed by the reeds 67 and 70 which is free from lost motion, and by swinging this lever 66 on its reed fulcrum it will be apparent that the spindle 5 may be moved axially. The lower lug 61 is slidably guided in a slot 73 in the housing 68, thus holding the collar 17 against rotation. The limits of axial motion of the spindle 5 may be determined by a pair of adjustable stop screws 75 (see Figure 7) between which the lever 66 extends and carried by lugs 76 on the forward face of the casing 68 which houses the rear end of the spindle, the lever 66 as shown having hardened headed abutments 78 in position to contact with the stop screws 75.

The angular position of the lever 66 may be varied as desired, and micrometric means may be provided for swinging it to move the spindle axially to bring the work against the grinding wheel for grinding the tapered portions of the bore as will later appear. This micrometric adjusting means is shown best in Figure 7, and comprises a bar 80 slidable through a bearing bracket 81 and having its forward portion externally threaded as at 82. Cooperating with these threads are mating internal threads on a sleeve 83 journaled in the bracket 81 and held against axial motion by an annular head 84 at one end, and a wheel 85 at the other end, bearing against opposite faces of the bracket 81, and held in position by a nut 86 threaded on the forward end of the sleeve 83 and held in position as by a set screw 87. This wheel 85 is provided with a handle 88 by which it may be turned and is also provided with a graduated peripheral portion at 89 with which cooperates an index element 890 carried by the bracket 81. The rear or outer end of the bar 80 is provided with a flattened portion extending into a guide element 81a (Figure 1) and across this portion is adjustably slidable the inner end of a flexible strip 90, the rear end of which is suitably secured to the outer end portion of the lever 66, as by a clamping cap 91 secured by a screw 92. This strip 90 may be adjustably secured at either end portion to its adjacent part, either the lever 66 or the bar 80. In Figure 2 it is shown as adjustably clamped to the lever 66, a screw knob 95, which may act as a clamp and also as a handle which may be grasped by the operator, being employed to clamp the strip 90 in position. In Figure 7 this adjustment is between the strip 90 and the bar 80, the strip being provided with a slot 97 through which extends a screw 98 provided with a clamping thumb nut 99. If the strip 90 is fixedly held to the lever 66, the outer end of this lever is preferably provided with a knob 100 by which it may be grasped by the operator for a purpose which will later appear.

From this construction it will be seen that the lever 66 may be adjusted by hand to the desired point, allowing the strip 90 to slide relative to one or the other of its end adjustments and then may be clamped in position, whereupon by rotating the wheel 85 the lever may be further moved in either direction, the extent of motion being indicated by changes in registry of the graduated dial 89 with reference to the reference element 890. This is for a purpose which will later appear.

Grinding wheel mounting.

The grinding wheel slide 110 may be mounted

on the machine for motion from and toward the work carriage in the manner shown in the Arms Patent No. 2,310,338, but for the purpose of this invention the grinding wheel spindle is not directly carried by this wheel slide. Instead the wheel spindle 111 is journaled for rotation in a carriage 112 which is mounted for motion on the wheel slide 110 but at an angle to the direction of motion of this slide, this angle corresponding to the taper of the taper bore portion of the work piece. This mounting is illustrated best in Figures 12 to 15. The wheel slide 110 has a pair of upwardly extending portions 114 which have clamped therein a pair of spaced guide bars 115 (see Figures 12, 13 and 15). The carriage 112, which carries a wheel head 116 carrying the wheel spindle 111, has forward and rear walls 118 and 119 which extend down on opposite sides of the upstanding portions 114 of the wheel slide and these walls 118 and 119 are provided with bushings 120 which are mounted on end portions of the guide bars 115 which extend beyond opposite faces of the portions 114, as on preloaded ball bearings 121 and 122. The forward ball bearing 121 is covered over by a cap 123 which houses the outer end of a plunger 124 slidable in the outer end of a socket 125 in the adjacent end of the guide bar 115 and pressed outwardly by a spring 126 seated in the socket 125. This plunger 124 acting on the cap 123, presses the caps 116 of the wheel carriage forwardly along the inclined guide bars 115 as far as is permitted by the engagement of a cam contoured rod 128 journaled in the portion 119 of the wheel carriage, the cam face of which bears against a rod 129 mounted for axial motion in one of the portions 114, its inner end bearing on a face 130 of a second cam bar 131 also journaled in the portion 114. This cam bar 131 also has a face 132 which bears against a plug 133 mounted in a bore 134 of the portion 114 and backed up by an adjusting screw 135. This plug 133 determines one angular limit of motion of the cam bar 131 and this limit of motion determines also the forward limit of motion of the rod 129. The cam bar 131 is provided with an actuating handle 140 at its forward end, while the cam bar 128 has a similar actuating handle 141 at its forward end. This latter handle 141 may be turned toward and from a limiting position determined by engagement of a pin 142 thereon with a fixed stop pin 143. The portion of this cam bar which bears on the rod 129 is so shaped that as the handle 141 is turned between its positions, the wheel carriage is moved axially for a short distance sufficient to bring a cam follower 158, to be later described, into or out of operative relation to a cam by the motion of which automatic traverse of the carriage along the inclined bars 115 may be produced. The angular motion of the handle 140 may act to give a further extent of motion of the wheel carriage back of its automatic reciprocation and independent of that produced by rocking of the handle 141, this being sufficient to move the wheel carriage in a path during which the tapered face of the wheel may be trued, as will later appear.

The reciprocating means for the carriage is shown best in Figures 12, 13 and 14. The rear end of the wheel carriage has secured thereto, as by screws 150, a yoke member 151 having a pair of side jaw portions 152 which have between them a cam in the form of an eccentric 153 carried by the upper end of a shaft 154. This eccentric 153 carries the inner raceway 155 of a ball bearing 156, the outer raceway 157 of which is stationary as the eccentric revolves, and when the handles 141 and 140 are in their lowered position shown in Figure 12, the cam follower consisting of an abutment 158 micrometrically adjustable through a cross bar 159 fixed to the rear ends of the jaws 152 engages on this outer raceway. As the eccentric 153 is rotated, the abutment 158 follows the motion of the outer raceway in the direction of traverse permitted by the guide bars 115, the springs 126 holding the abutment 158 against the raceway member 157. Thus by rotation of the eccentric, a reciprocatory motion of the wheel carriage in a direction angular to the direction of motion of the wheel slide takes place, this being through a small amplitude but sufficient to provide the desired traversing of the tapered face of the grinding wheel along the tapered face of the work piece. Rotation of the eccentric 153 is produced by rotating the shaft 154 in its ball bearings 160, and to this end the shaft 154 has fixed thereto a worm wheel 161 (Figures 12 and 16) with which meshes a worm 162 fixed to a shaft 163 journaled in a casing 1630 carried by the wheel slide. This shaft 163 is provided with a belt pulley 164 from which it may be driven as by a belt 165 from a motor 166 (see Figure 2) carried by the wheel slide 110.

By turning the handle 141 from its lowered position shown in Figure 12, the wheel carriage may be retracted along the guide bars 115 sufficiently to bring the abutment 158 out of contact with the eccentric ball bearing element so that no angular reciprocation of the wheel carriage with the wheel may be produced. The abutment 158, which was previously described as micrometrically mounted, may have the graduated micrometer thimble 169 by which its position of adjustment may be read, this being for a purpose which will later appear.

One form of work piece and the grinding wheel for performing the desired operations thereon is illustrated in Figures 3 to 6. The work piece, as shown in these figures, comprises a cylindrical body 200 having a rear end portion 201 of somewhat increased diameter and a central cylindrical bore 202. At the forward end of this cylindrical portion it opens up into an enlarged cavity 203 from which a tapered bore portion 204 extends to a nozzle aperture 205. The grinding wheel for operating on these bores has a cylindrical portion 206 terminating in a tapered conical end 207. The cylindrical portion 206 is employed to grind the cylindrical portion 202 of the bore, and the conical portion 207 is employed to grind the conical surface 204. The cylindrical portion of the bore 202 is traversed during the grinding operation by the cylindrical portion 206 of the grinding wheel, this traverse being effected by the oscillation of the wheel slide, this oscillation being effected between the limits shown in full and dotted lines of Figure 3. This traverseing motion of the wheel slide may be effected by power means which may be identical with that shown in the Arms Patent No. 2,310,338, to which reference has previously been made. The means which determines the inner limit of such traversing motion, this being the full line position of Figure 3, is determined by the impingement of a control element 208 upon a stop dog 210 shown in Figures 1 and 18, but in order that the carriage may be moved an additional amount to bring the grinding wheel tapered end portion nearer to the taper surface to be ground, this

stop dog 210 is mounted so that it may be lifted by the operator out of operative position, and as shown in Figures 1 and 18, this may be accomplished by providing a slot 211 in the dog stop 210 through which passes a fulcrum pin 212. Likewise, in order to advance the grinding wheel from time to time as the conical end portion of the grinding wheel is worn or trued off, and to make sure that the traverse extends in far enough for the cylindrical portion 206 of the wheel to clear the inner end of the cylindrical bore, the stop dog 210 may be adjusted to the right, as shown in Figure 18, by means of an adjusting screw 213. During this grinding operation of the cylindrical bore 202, the wheel carriage is held retracted with the abutment 158 out of operative relation to the eccentric 153 so that the entire motion of the grinding wheel is lengthwise of the spindle axis.

When the desired extent of grinding of the cylindrical portion 202 has been completed and the wheel slide has been retracted, as by the mechanism fully described in the Arms Patent No. 2,310,338, the parts are then adjusted for the grinding of the taper bore portion 204. The wheel slide is then moved forward (to the left in Figures 1 and 2) until it is stopped by impingement of a facing stop element 220 carried by the wheel slide against a cooperating stop 221 adjustably carried by the bed of the machine (Figure 18). While these stops 220 and 221 are not new with this machine, being shown in the Arms Patent No. 2,310,338, to which reference has heretofore been made, they have been illustrated herein as they are used in a particular manner in the cycle of operations. The stop 220 may be placed at adjustable distances from the forward face of the wheel slide, and for this purpose this stop may be provided with a series of stop rods 222 supported at various angular positions about its axis and of varying lengths, any one of which may be brought to a position in line with an abutment 223 on the wheel slide, the others of the series being placed opposite to openings 225 in the wheel slide into which they may extend if they are of sufficient length to do so when the selected rod 222 is in position to be stopped by the abutment 223. By this means the amount of extension of the stop 220 may be adjusted from one to another of any selected of a number of different positions, each position being definitely predetermined by the effective length of the rod 222 then in operative position.

The position of the stop 221 is adjustable, and for this purpose it is shown as provided with a threaded shank 230 with which is engaged a nut 231 journaled in a casing 232 secured to the bed of the machine. This nut 231 has a portion of its periphery formed as a worm wheel with which cooperates a worm 233 on a shaft 234 which carries a hand wheel 235 at its outer end by which it may be turned.

In the position of the wheel slide where the facing stops are in contact, the conical portion of the grinding wheel may not be sufficiently far advanced to contact with the bore of the work piece. The work piece then may be brought up gently into contact with this portion of the grinding wheel and this may be done by releasing the strip 90 at its releasable end and with the indications on the wheel 85 turned to zero at the indication 890, and the outer end of the lever 66 may then be moved toward the right until the operator feels the work contacting with the conical end of the grinding wheel, whereupon the strip 90 is clamped in position, and the further motion of the work piece toward the wheel to feed it against the wheel is effected to the desired extent by rotating the hand wheel 85 until the desired depth indication on the indicator 89 has been reached.

If desired the motor 14 may be set sufficiently to the right to bring its belt pulley to the right of the pulley 10 so that the pull of the belt biases the work spindle axially to gently bring the work to contact the grinding wheel while the strip 90 is released. Gentle contact between the work and wheel is important to avoid breaking the wheel and is facilitated by the flexible reeds and preloaded thrust bearings at the plungers 124 which eliminates errors from backlash and running clearances and eliminates frictional drag which would reduce sensitivity of control.

During the feeding of the work piece toward the grinding wheel, the grinding wheel is oscillated parallel to the wheel taper by releasing the wheel carriage from its rearward position by rocking the handle 141 to the left, the handle 140 being in its lowered position, allowing the abutment 158 to come into operative engagement with the eccentric. This being rotated by its driving motor, the wheel is given a slight oscillation in the lengthwise direction of the line of contact between the taper portion of the wheel and the work piece.

Figures 4, 5 and 6 illustrate the various relationships between the wheel and the work for the start of the taper grinding operation. In Figure 4 the relative position between the wheel and the work piece in shown where the wheel head has been advanced against the facing stop. Figure 5 shows the work piece advanced into contact with the wheel, while Figure 6 shows in dotted lines the traverse limits of the taper portion of the wheel with relation to the tapered face of the work piece during the grinding of this tapered face, the wheel then being oscillated in a path angularly related to its axis and in the inclined direction of the guides 115. When the grinding has thus proceeded to the desired extent, the work piece is retracted from the wheel by reversing the rotation of the hand wheel 85, the wheel head is returned to its retracted position out of driven relation from the eccentric 153 by returning the handle 141 to the retracted angular position with the pin 142 engaging the stop pin 143 Figure 12, and the wheel slide is retracted and made ready for a subsequent grinding operation.

In some cases the work piece may be provided with a second tapered face 250, as shown in Figure 19, at the rear end of the cylindrical bore 202, this taper being on the same angle as the taper portion 204 adjacent to the nozzle orifice. This face 250 may be also be ground by the taper grinding portion 207. The wheel may be positioned to take care of this grinding operation by causing the oscillation produced by the eccentric 153 to be imparted thereto while the wheel is in a position further removed from its position relative to the work axis than is its position when grinding the taper surface 204 adjacent to the nozzle orifice. It is also in a different axial position. This may be accomplished by adjusting the facing stop 220 to a different axial position, as by the use of a stop rod 222 of greater length than that utilized during the grinding of the inner tapered surface 204.

The further separation of the wheel from the

work axis may be accomplished by the use of a removable stop **260** of the proper thickness which can be interposed between the eccentric **153** and the yoke end member **159**, as shown in Figures 20 to 22. This member **260** may be pivoted on a pin **261** passing through a slot in one of the yoke arms **152***a* and may be provided with an actuating handle **262** by the manipulation of which it may be turned into the operative position inwardly of the yoke end member **159** shown in Figures 20 and 21, and in full lines in Figure 22, in which position, it acts to retract and hold the wheel retracted away from its normal axial position for cylindrical grinding into the position where it may engage the tapered face **250**. The stop **260** may, however, be thrown out of operative position into the dotted line position of Figure 22, in which case the wheel carriage may move forward and, provided the handles **140** and **141** are in position to permit it, till the micromentrically adjustable element **158** is in operative relation to the eccentric, in which position the wheel is in condition and position for operating on the tapered bore **204** adjacent to the nozzle.

It will be understood that that portion of the tapered wheel adjacent to the point of the taper is less effective for grinding than the portion further removed therefrom because of the higher rate of cutting speed of the individual grits the further they are removed from the axis of rotation, and that a grit at the extreme point or lying in the axis of the wheel in ineffective to cut. It is therefore, important that when the tapered portion **204** adjacent to the orifice of the nozzle is being ground, the wheel be presented thereto as far back from the point as possible, but without the wheel contacting with the diametrically opposite part of the surface. Referring, for example, to Figure 6, the contact between the wheel and the work is desired at one side of the axis of the wheel, but not on the other. Consequently the relative adjustments of the wheel and work for grinding this tapered portion must be quite precise and the amount of oscillation of the wheel small in order that the grinding contact may be held as far as possible away from the wheel axis. Where the nozzle to be ground is of small diameter having a nozzle aperture of as small as .04" diameter, the adjustments must be made very accurately in order to maintain this desired relationship, and often the outer portion of the taper part of the wheel cannot be brought into grinding relation to the work at this taper surface because of the limitations afforded by contact with the opposite face of the work from where contact is desired. Since this larger diameter portion, however, is more advantageous for grinding than is the small diameter portion, it may be made use of when the nozzle is provided with a rear taper face such as **250** in Figure 19, and the parts should be so proportioned that this larger diameter portion of the tapered face is in operation for this portion of the grinding.

Means for truing the wheel, both for the cylindrical and tapered portions may be provided, to this end a truing device being shown at **270** in Figure 2, this being supported on the inner face of the work slide and being rockable forwardly and backwardly into and out of proper position with respect to the cylindrical surface of the wheel when the wheel is moved by motion of the wheel slide, and in proper relation to the taper portion of the wheel when the wheel is moved by motion of the wheel carriage,

The various operations performed by the apparatus as thus described may be accomplished as follows.

Setting up

The machine is set up with the dressing diamond set to the diameter of the cylindrical part of the hole ground and to finish size.

One position of the turret facing stop on the wheel slide is set so that the tapered portion of the wheel will be in position to be dressed by the diamond when the wheel carriage is oscillated.

A second position of the same turret stop is set to a known length longer than the first, which increase is equal to that axial distance between the diamond and the cone of the seat of the work to be ground. This is an approximate adjustment, since the work spindle is adjustable longitudinally.

The eccentric driving the wheel carriage traverse motion is adjusted to traverse the carriage only the small amount necessary to break up grinding marks, say, .010" stroke.

The micrometer thimble **169** is adjusted so that the axis of the wheel is only a small amount, say, .002" in back of the work axis when the work feed is at a setting for the finish size of the cylindrical hole and the stop **158** is contacting the low point of the eccentric, that is, with the wheel carriage at the left hand limit of its stroke.

Operation

1. The cylindrical portion of the wheel is dressed in the conventional manner with the lever **141** in position to hold the carriage away from the eccentric, and the stock is removed from the wheel by feeding the work slide toward the front.

2. After the cylindrical portion of the wheel has been dressed, as noted in the preceding paragraph, the wheel slide is moved to the left until the facing stop **220** set in dress position by the selection of the proper element **222** engages the stop **221**. The wheel is then caused to traverse the dressing tool by hand operation of the lever **140**, the lever **141** being retained in its position in which it was put for the cylindrical wheel dressing. The stock is removed from the wheel at the taper portion by retracting the feed screw hand wheel for the facing stop **221**, permitting the wheel slide to move toward the left. The amount of turning of this hand wheel during the dressing operation is noted and the adjusting screw **213** for the right hand reversing dog is adjusted to the same amount. This compensates in the inner limit of stroke of the wheel while it is grinding the cylindrical portion of the bore, for wear and truing on the taper portion of the wheel.

3. The turret facing stop **220** is then turned to taper grinding position with the proper element **220** in operative position, but the position of the opposite facing stop **221** is allowed to remain as it was after the dressing adjustment.

4. The work slide is then backed off by actuation of its cross feed mechanism.

5. The cylindrical portion of the hole in the work piece is then ground in the usual manner with the automatic traverse and with the lever **141** of the wheel carriage still in the same angular position to operatively disengage the carriage from the cam so that it has no angular motion. The cylindrical portion of the hole in the work is then ground to finish size.

6. The right hand lever **141** is then turned

down to engage the wheel carriage with the eccentric for the angular traverse, and if the thimble 169 has been adjusted as previously directed, the axis of the wheel will be about .002" back of the work axis at the left hand end of the angular stroke. Rotation of this eccentric now produces the reciprocation of the wheel carriage parallel to the grinding wheel taper.

7. The main wheel slide is then moved forward with the facing stop 220 adjusted for the taper seat grinding in the same position at which it was positioned for the truing of the tapered face.

8. Assuming that the work is now positioned in the chuck that the tapered seat is uniform in relation to the work spindle, it is not necessary to release the work spindle thrust lever from its micrometric feeding mechanism. However, if there is a wide variation or when a new wheel is put on, the strip 90 is disengaged at one or the other of its ends and the lever 66 is adjusted until the operator feels the contact between the wheel and the taper seat, after which the reed is reclamped, or provided there is sufficient axial thrust on the spindle through the belt connection to its driving motor, as previously described, this will bring the work axially into the proper position for tightening the strip 90 to both the lever and the micrometric adjusting device.

9. The work spindle is then fed axially to grind the taper seat by rotation through the desired extent of the hand wheel 85. When this taper seat has been ground to the desired depth, the reading on the feed 89 is then noted and the micrometer thimble 169 on the wheel carriage is adjusted to correspond. This setting of the thimble maintains predetermined relative spacing of the wheel axis and the work axis. The wheel slide can be withdrawn to the right away from the facing stop at any time for inspection of the seat and returned to grinding position without changing the adjustments.

10. Assuming that there is no taper face 250 to be ground at the outer end of the cylindrical hole 202, the wheel slide is then withdrawn, the operation being complete, the work pieces are changed, and the cycle is repeated. The work carriage cross feed should then be backed off. If, however, there is an outer taper, as the taper 250 of Figure 19, to be ground, further steps are necessary before removing the work or backing off the cross feed as follows.

11. Without changing the adjustment of the cross feed on the work, the wheel slide is withdrawn to the right and the work spindle is moved to the left.

12. The stop element 260, shown in Figures 20 to 22, is then inserted between the eccentric and the yoke end member 159, which can be done by swinging the lever 140 in a direction to withdraw the wheel carriage sufficiently.

13. The third position of the facing stop 220 for grinding the outer taper is then engaged.

14. The outer taper 250 is then ground by feeding the work spindle axially to the right, the wheel carriage then being oscillated by the action of the eccentric against the element 260.

15. On completion of the grinding of this tapered surface, the wheel slide is moved to the right to change the work preparatory to repeating the cycle of operations, the work slide cross feed being backed off before starting operation on the next work piece.

From the foregoing description of certain embodiments of this invention, it should be evident to those skilled in the art that various further modifications and changes may be made without departing from its spirit or scope.

We claim:

1. In combination, a wheel carriage, a grinding wheel carried by said carriage, means supporting said carriage for reciprocatory motion, a rotary shaft, a cam on said shaft, a yoke on said carriage within which said cam is positioned, means for rotating said shaft, means biasing said carriage to press one end of said yoke against said cam whereby the rotation of said shaft causes reciprocation of said carriage, and an abutment carried by said yoke and movable into or out of position between said cam and said yoke to thereby change the effective relation between said carriage and cam.

2. In combination, a work support, a rotary work-carrying spindle journaled on said support and movable axially relative thereto, a collar journaled on said spindle and axially fixed with relation thereto, a lever mounted for swinging motion in a plane parallel to the axis of said spindle, a connection from said lever to said collar whereby swinging of said lever moves said spindle axially, a micrometer adjustment means connected to said lever for swinging said lever, a slidable connection between said adjusting means and lever, and means for clamping said connection against sliding.

3. In combination, a work support, a rotary work-carrying spindle journaled on said support and movable axially relative thereto, a collar journaled on said spindle and axially fixed with relation thereto, a lever mounted for swinging motion in a plane parallel to the axis of said spindle, a connection from said lever to said collar whereby swinging of said lever moves said spindle axially, a bar mounted for axial motion, a member having threaded connection with said bar for axial adjustment of said bar by rotation of said member, and a connection from said lever to said bar causing the axial motion of said bar to swing said lever.

4. In combination, a work support, a rotary work-carrying spindle journaled on said support and movable axially relative thereto, a collar journaled on said spindle and axially fixed with relation thereto, a lever mounted for swinging motion in a plane parallel to the axis of said spindle, a connection from said lever to said collar whereby swinging of said lever moves said spindle axially, a bar mounted for axial motion, a member having threaded connection with said bar for axial adjustment of said bar by rotation of said member, and a connection from said lever to said bar causing the axial motion of said bar to swing said lever, said connection having a releasable engagement with one of the parts connected thereby.

5. In combination, a work support, a rotary work-carrying spindle journaled on said support and movable axially relative thereto, a collar journaled on said spindle and axially fixed with relation thereto, a lever, a plurality of reeds fulcruming said lever on said support for motion in a plane substantially parallel to the axis of said spindle, a reed securing said lever to said collar whereby swinging of said lever moves said spindle axially, and means actuable to swing said lever.

6. In combination, a work support, a rotary work-carrying spindle journaled on said support and movable axially relative thereto, a collar journaled on said spindle in pre-loaded thrust anti-friction bearings, a lever, a plurality of

reeds fulcruming said lever on said support for motion in a plane substantially parallel to the axis of said spindle, a reed securing said lever to said collar whereby swinging of said lever moves said spindle axially, and means actuable to swing said lever.

7. In combination, a wheel carriage, a grinding wheel on said carriage having a tapered face portion, a work holder, means for moving said wheel carriage parallel to one side of said tapered face to produce grinding of a tapered portion of the work on said work holder by said tapered face, means for feeding the work holder axially of said wheel against said wheel for the grinding of said tapered face, means supporting said wheel carriage for adjustment axially of said wheel, and means for adjusting said wheel carrier axially relative to said axial feeding means to maintain said tapered face in predetermined relation to said axial feeding means regardless of wheel wear and truing

8. In combination, a wheel carriage, a grinding wheel on said carriage having a cylindrical and a tapered grinding face, a work holder, means for moving said carriage and work holder relatively parallel to the wheel axis to effect traverse between said cylindrical wheel face and a cylindrical face of work on said work holder, means for limiting such axial movement in one direction, means for relatively moving said carriage and work holder parallel to one side of said tapered face to grind a tapered face of the work, and means for adjusting said limit of said relative movement of said carriage and work holder parallel to said axis to compensate for shortening of said cylindrical wheel face by wear and truing of said tapered face.

9. In combination, a work support, a rotary work carrying spindle journaled on said support and movable axially relative thereto, a collar journaled on said spindle and axially fixed with relation thereto, a bar mounted for axial movement substantially parallel with said spindle, and a connection between said bar and collar causing the axial motion of said bar to move said spindle axially.

10. In combination, a work support, a rotary work carrying spindle journaled on said support

and movable axially relative thereto, a collar journaled on said spindle and axially fixed with relation thereto, a bar mounted for axial movement substantially parallel with said spindle, and a connection between said bar and collar causing the axial motion of said bar to move said spindle axially, said connection being adjustable to thereby adjust the limits of axial motion of said spindle corresponding to a predetermined extent of axial motion of said bar.

11. In combination, a work support, a rotary work carrying spindle journaled on said support and movable axially relative thereto, a collar journaled on said spindle and axially fixed with relation thereto, a lever mounted for swinging motion in a plane parallel to said spindle and operatively connected to said collar, a bar mounted for axial movement substantially parallel with said spindle, a flexible rod carried by said bar and lying substantially parallel to said axis, and a clamp carried by said lever and adjustably fixed along said rod and causing the axial motion of said bar to move said spindle axially.

MERTON H. ARMS.
PAUL A. GROBEY.
HAROLD M. DAY.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
95,342	Harper	Sept. 28, 1869
1,530,242	Cumner et al.	Mar. 17, 1925
1,989,792	Drader	Feb. 5, 1935
2,083,682	Balsiger et al.	June 15, 1937
2,139,896	Johnson	Dec. 13, 1938
2,167,647	Gideon	Aug. 1, 1939
2,210,273	Wildhaber	Aug. 6, 1940
2,237,583	Birkigt	Apr. 8, 1941
2,356,499	Beduneau	Aug. 22, 1944
2,414,182	Wessman	Jan. 14, 1947

FOREIGN PATENTS

Number	Country	Date
664,897	France	Sept. 11, 1929