J. BATH.

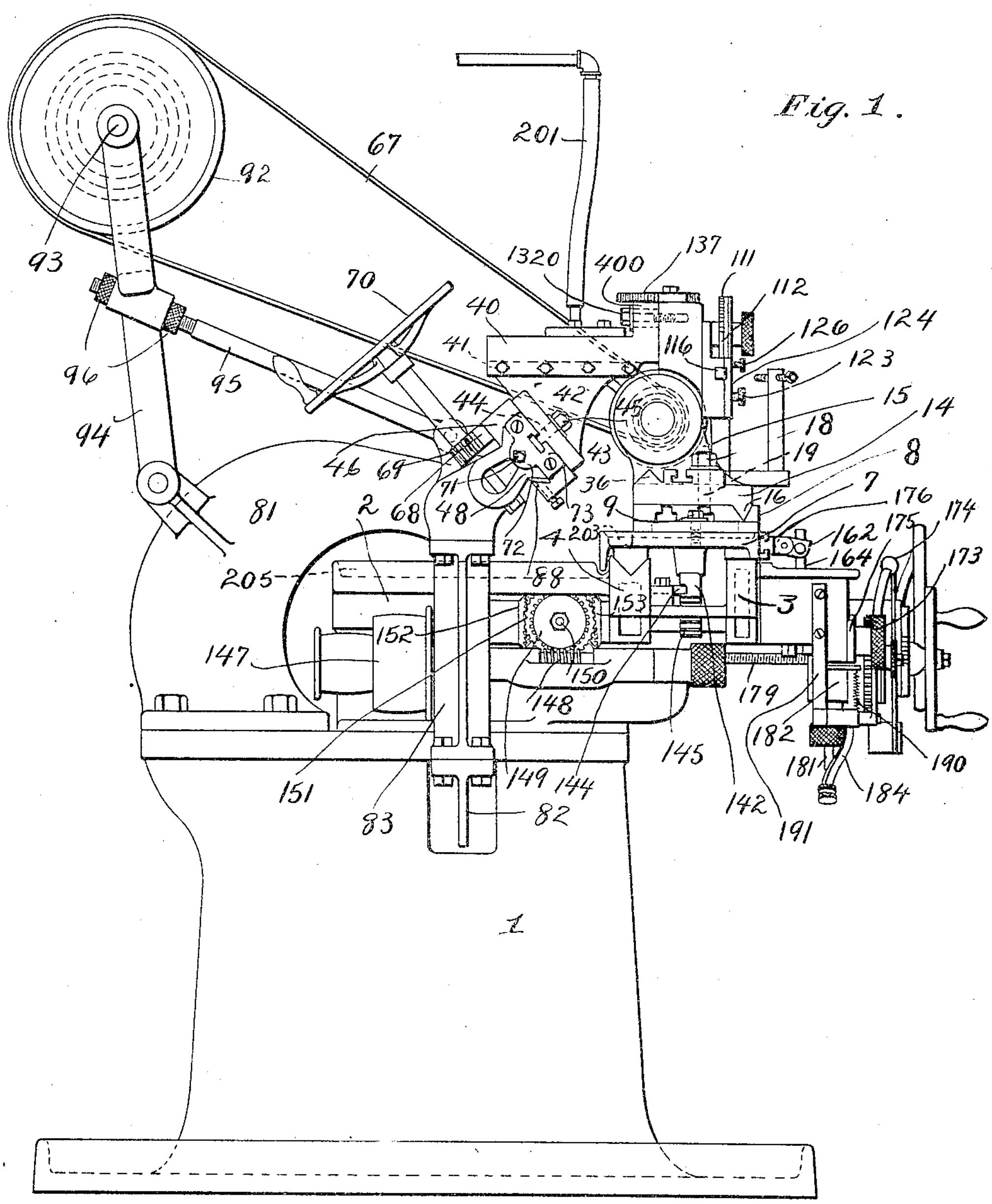
GRINDING MACHINE.

APPLICATION FILED JULY 22, 1907.

1,036,543.

Patented Aug. 27, 1912.

7 SHEETS—SHEET 1.



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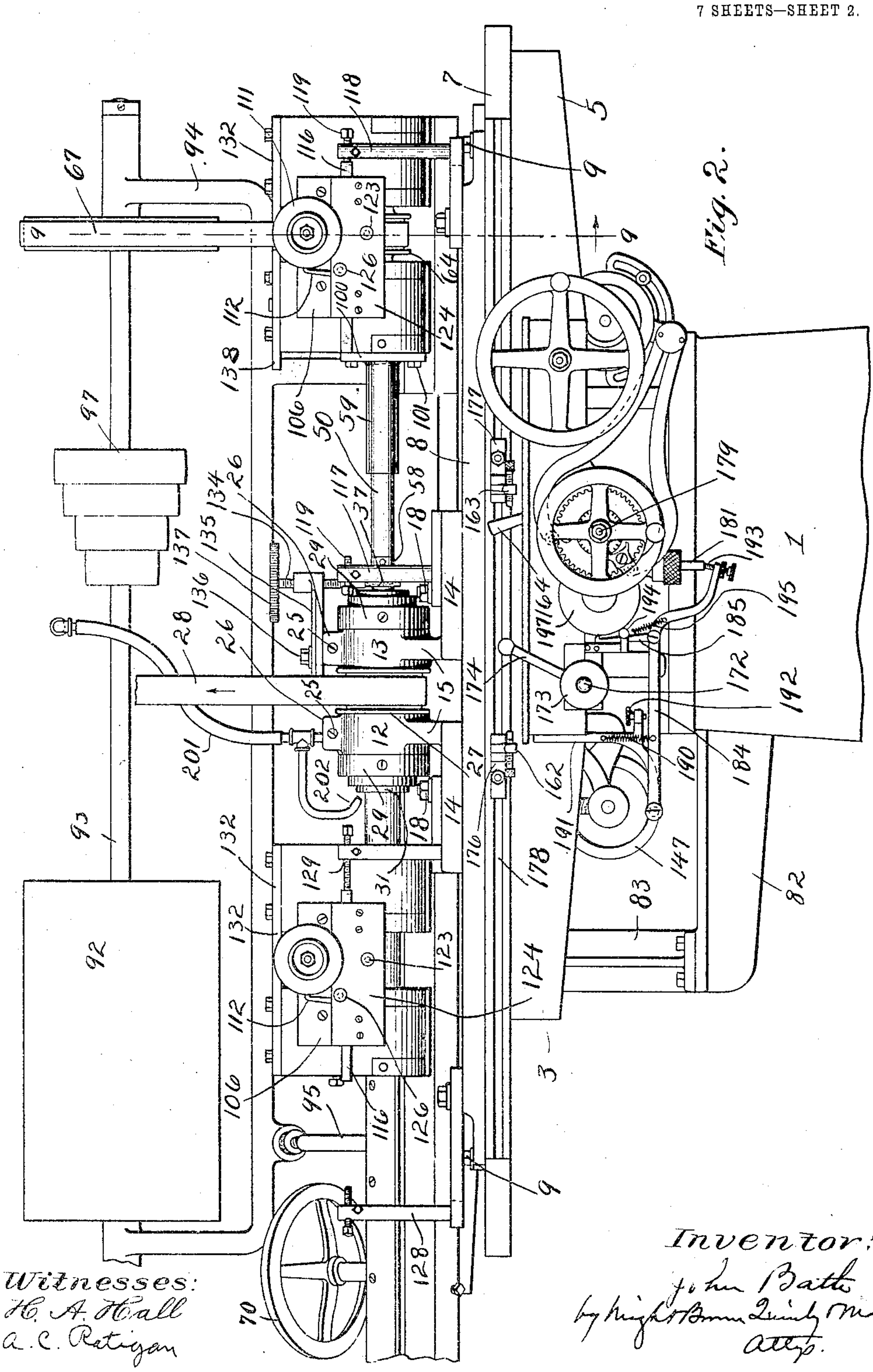

Fig. 2.

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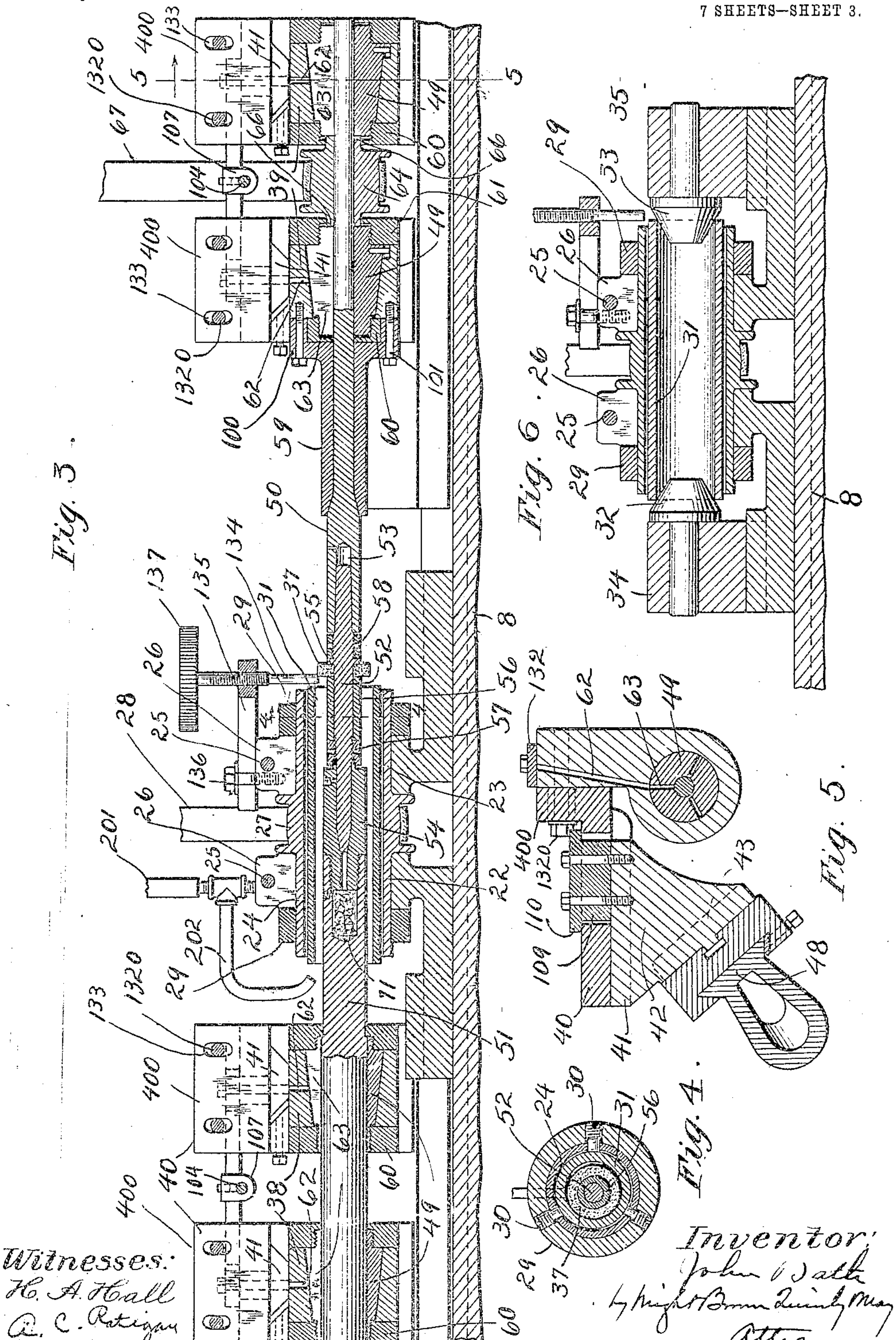

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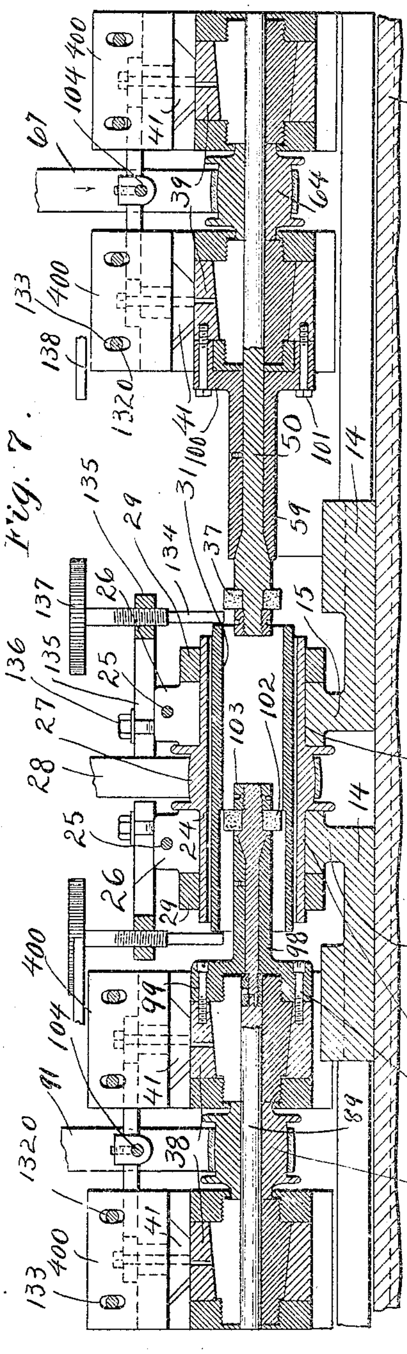

Fig. 7.

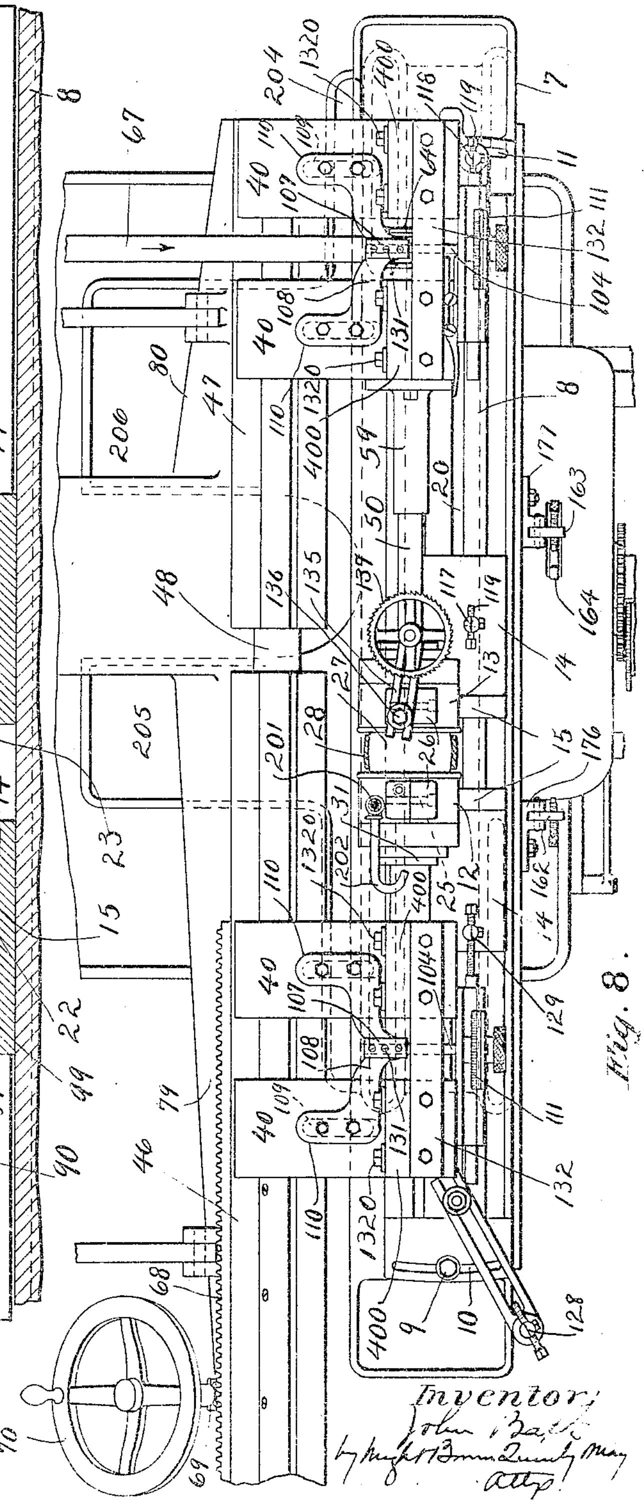

Fig. 8.

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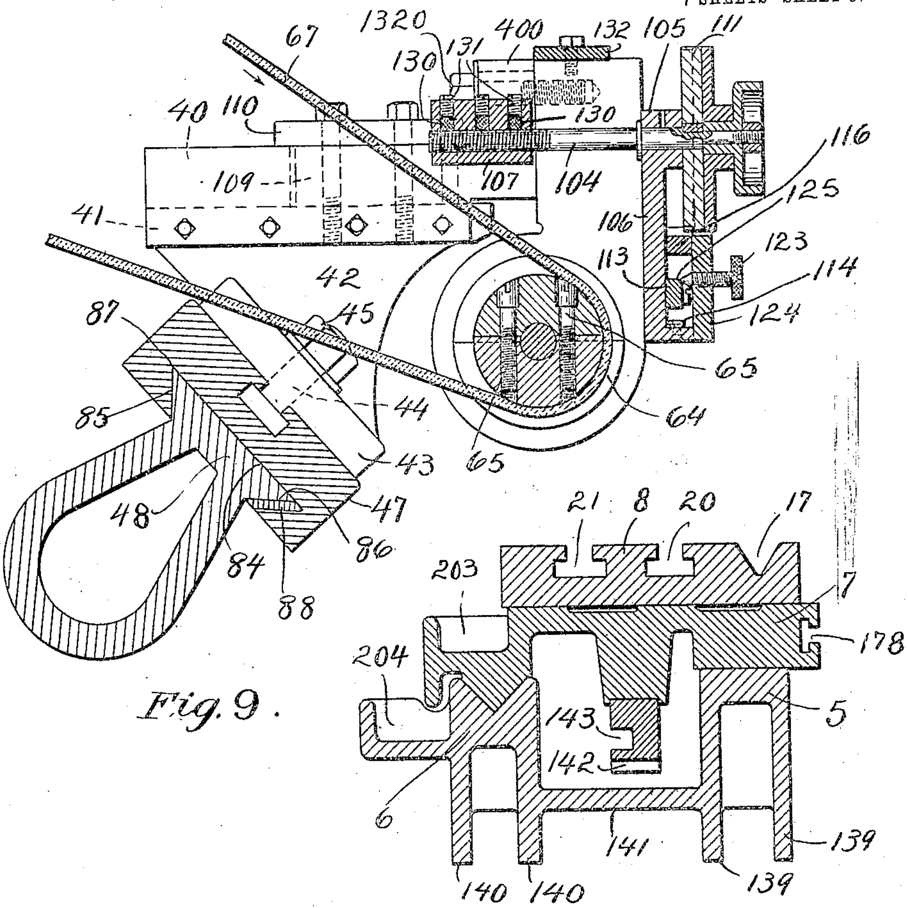

Fig. 9.

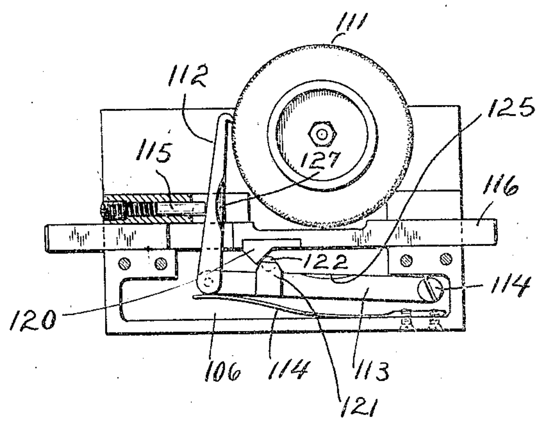

Fig. 10.

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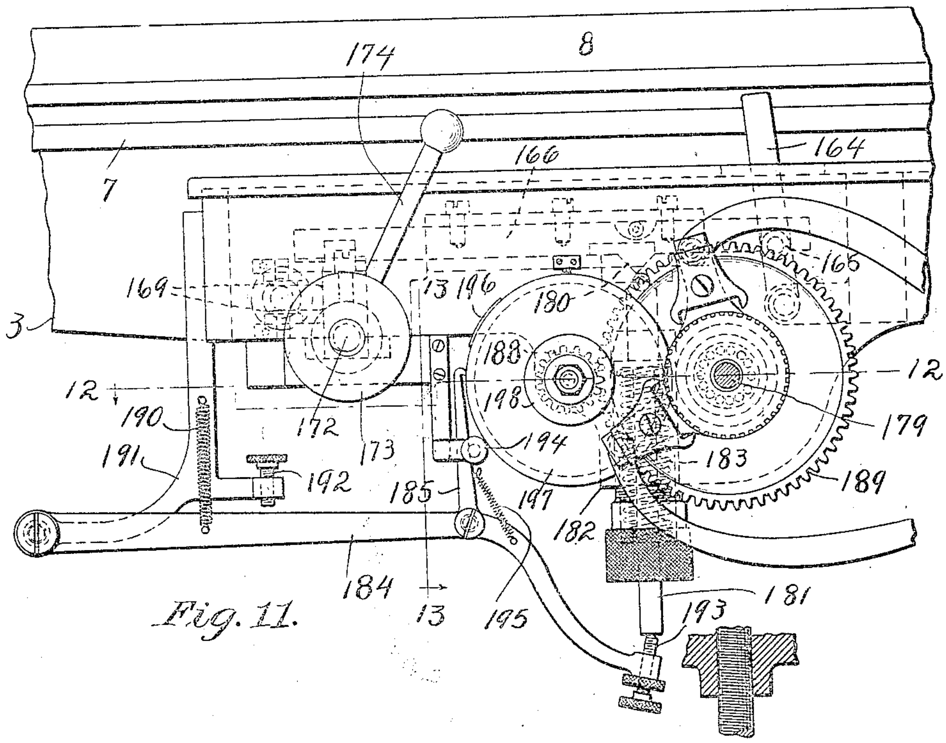

Fig. 11.

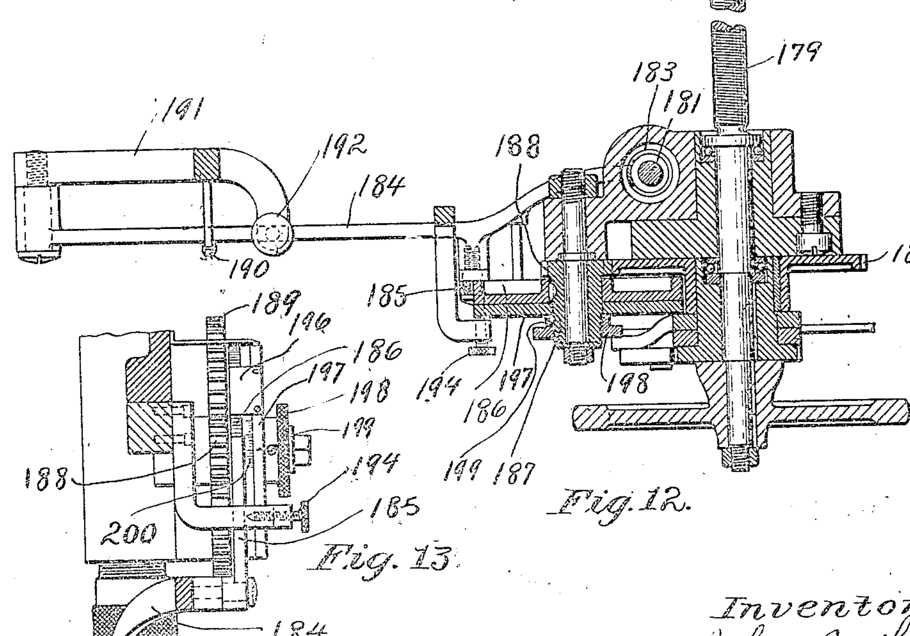

Fig. 12.

Fig. 13.

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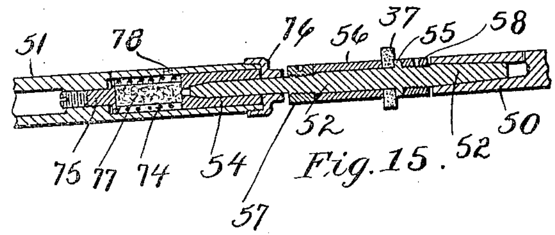

Fig. 15.

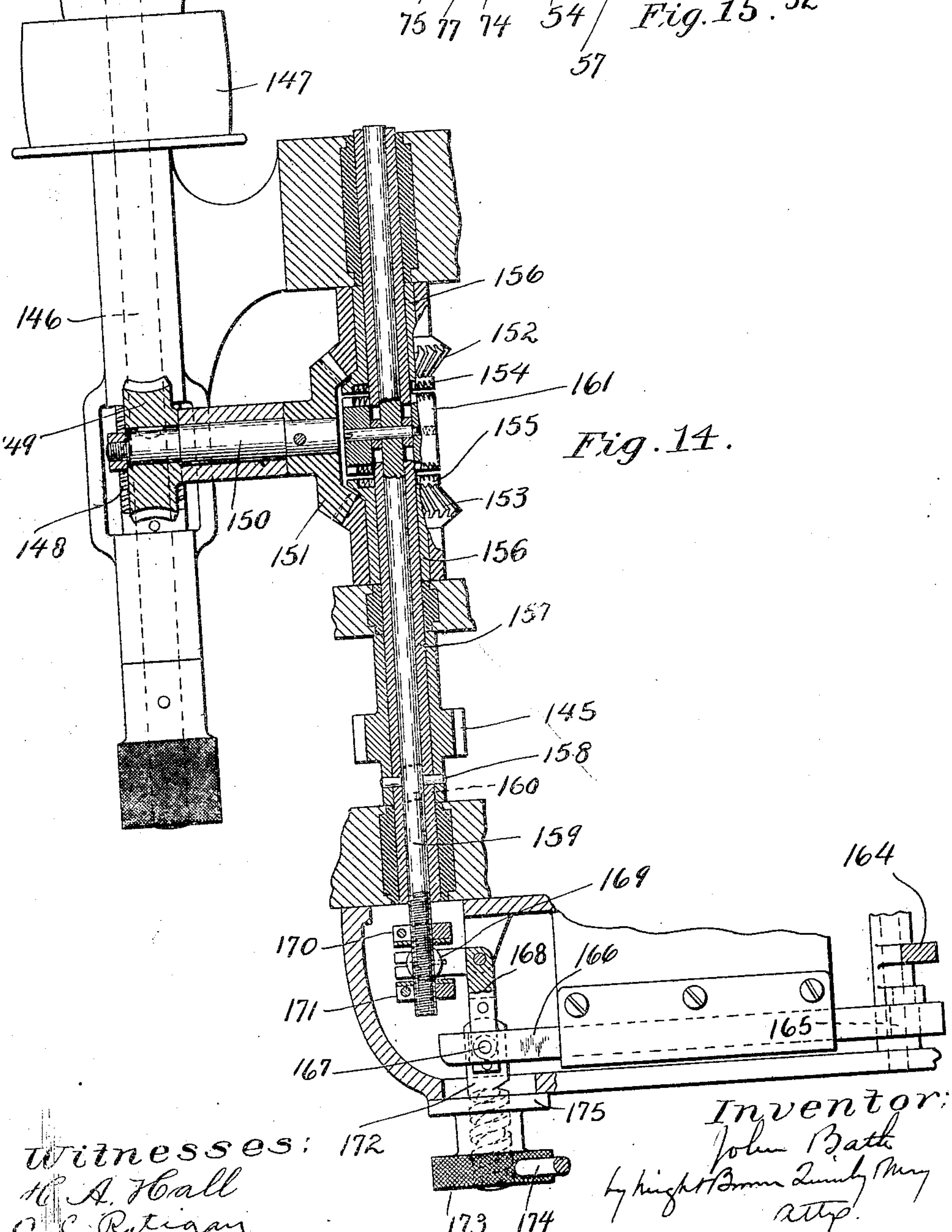

Fig. 14.

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UNITED STATES PATENT OFFICE.

JOHN BATH, OF FITCHBURG, MASSACHUSETTS, ASSIGNOR TO BATH GRINDER COMPANY, OF FITCHBURG, MASSACHUSETTS, A CORPORATION OF MASSACHUSETTS.

GRINDING-MACHINE.

1,036,543. Specification of Letters Patent. Patented Aug. 27, 1912.

Application filed July 22, 1907. Serial No. 385,007.

To all whom it may concern:

Be it known that I, JOHN BATH, of Fitchburg, in the county of Worcester and State of Massachusetts, have invented certain new and useful Improvements in Grinding-Machines, of which the following is a specification.

The present invention relates to grinding machines, particularly those designed to perform internal work, and its primary and general object is to enable such machines to work with a higher degree of accuracy than has hitherto been possible.

Subsidiary objects which are necessary to attain the general object above stated are to provide constructions by which the grinding tool or tools may be held with great stiffness and without looseness or back-lash, which would lead to inaccuracy, and to provide fine adjusting means for positioning and feeding the tool or tools and the work, and for measuring the amount of such adjustment or feed.

The various details of construction by which I achieve the results indicated above are described in the following specification, and are illustrated in the drawings forming a part thereof.

In the drawings,—Fig. 1 represents a side elevation of a machine embodying the preferred form of the principles of my invention. Fig. 2 represents a front elevation of the essential parts of the machine, the lower part of the base, and the extreme left-hand end of one of the tool slides being broken away. Fig. 3 represents a longitudinal axial section of the grinding tool holder and work holder in operative relation. Fig. 4 represents a cross section of the work and work-holding chuck on line 4—4 of Fig. 3. Fig. 5 represents a cross-section of one of the grinding tool supports on line 5—5 of Fig. 3. Fig. 6 represents a longitudinal section of the work-holding chuck, showing centering devices for the work in operative position. Fig. 7 represents a section similar to Fig. 3, but showing a plurality of tools for grinding internal work of two diameters simultaneously. Fig. 8 represents a plan view of the machine. Fig. 9 represents a cross-section of one of the tool-holders and the bed, table and carriage on which the work is held, taken on line 9—9 of Fig. 2. Fig. 10 represents a front elevation of one of the tool-feeding mechanisms. Fig. 11 represents a front elevation of the work-feeding mechanism. Fig. 12 represents a sectional plan of the same on line 12—12 of Fig. 11. Fig. 13 represents a cross-sectional elevation of the same on line 13—13 of Fig. 11. Fig. 14 represents a sectional plan of the driving and reversing mechanism for the work-supporting bed. Fig. 15 represents a sectional detail view of the tool-carrying spindle, showing a yielding bearing for the same.

The same reference characters indicate the same parts in all the figures.

Referring to the drawings, the machine is supported by a base or pedestal 1 upon which is supported a carriage 2 mounted to slide in ways from left to right and vice versa, as seen in Fig. 1. The character of the connection between the pedestal and carriage is the same in this machine as in the machine patented to me May 16, 1905, No. 790,099, to which reference is directed for details not illustrated herein.

Extending outward from opposite sides of the carriage are arms 3 4 5 and 6 which are faced off on their upper surfaces to form guides for a lower bed or table 7, which in turn is level on its upper surface and supports an upper bed or platen 8. The latter is pivoted centrally upon the lower bed and may be swung slightly for grinding tapered work, being held in any adjusted position by bolts 9 passing through slots 10 and 11. This construction is the same as in my prior patent above referred to. The work is adjustably supported on the platen 8 by head stocks 12 and 13, each of which has a base portion 14, and a standard 15 rising from the base. The bases of the head stocks have projecting downwardly V-shaped ribs 16 which enter a correspondingly-shaped groove 17 in the platen, and, by bearing against the corresponding sides of the slot, guide the head stocks so that they can be slid longitudinally in a straight line. The head stocks are clamped in any position of adjustment by nuts 18 on headed bolts 19 which enter under-cut grooves 20 and 21 in the platen.

The standards of the head stocks are internally bored out to provide bearings 22 and 23 for a work-holding chuck 24. This chuck consists of a sleeve which is centrally bored from end to end and has a cylindrical outer surface which turns in the bearings.

The latter are adjusted so as to fit the sleeve without looseness, by bolts 25 passing through ears 26 which project from the upper sides of the bearings where the latter are divided to permit this adjustment. On the middle of the chuck sleeve is formed a pulley 27 about which a driving belt 28 is passed to rotate the chuck and work. On the sleeve adjacent its opposite ends are collars or rings 29 which lie outside of the bearings and prevent the chuck from slipping out of either bearing. The latter, by reason of their connnection with the platen above described, are enabled to be moved toward and from each other to adjust their position for work of different lengths, and to enable them to be brought up against the faces of the collars 29 so that there will be no looseness and side play of the chuck and work. Each collar carries three or more set screws 30 which pass through slots in the sleeve and bear against the work pieces 31 to hold the latter centrally in the chuck.

In order to center the work quickly and accurately, I provide the devices shown in Fig. 6. These consist of conical headed studs 32 and 33 held in blocks 34 and 35 which are detachably mounted upon the bases 14 of the head stocks. The blocks are of such a height and the studs so located in them that the axes of the latter are at the exact height of the bearing axis, while they are positioned laterally by inverted V-shaped ribs 36 on the head stock bases entering grooves in the under sides of the blocks. When the blocks are moved toward each other, the conical heads enter the opposite ends of the tubular work piece and lift it into a central position where it is retained by screwing home the set screws. The blocks are then removed to permit insertion of the grinding tool. It will be understood that the use of these centering studs saves much time which would otherwise be wasted in turning the chuck with the pieces in it and adjusting the screws from time to time until the work runs true.

The grinding tool is represented by the emery wheel 37. Where the machine is adapted to grind work of the same diameter throughout it is held by a spindle which is supported at both ends on opposite sides of the work. These supports consist of heads 38 at the left-hand side of the machine, and 39 at the right. These heads are substantially duplicates of each other and are separate and independent except when connected together by the feeding means hereinafter described. Each head is mounted upon a slide 40 which is adapted to reciprocate transversely of the spindle on a guide 41. Each guide is formed upon a bracket 42 having a base 43 secured by a headed bolt 44 and nut 45 to either of the slides 46 or 47. The slide 46 supports the brackets for the left-hand heads 38, while that designated by 47 supports the heads 39 at the right. Both of the slides are mounted upon a guide 48 which runs parallel to the spindle axis and to the bed.

In each of the heads is held a bearing box 49 to contain the tool spindles whereon the grinding wheel is held.

It will be noted that the grinding-wheel holder or spindle shown in Fig. 3 is formed in three parts, the live spindle 50, a stationary bar or shaft 51, and an intermediate arbor 52. The stationary bar is clamped in its bearings so as not to rotate, and projects from the heads 38 toward the heads 39, being of a size to pass through the work. The live spindle rotates in its bearings and projects therefrom toward the heads 38. In its end it has a tapered socket 53 into which the tapered right-hand end of the tool arbor 52 is driven so as to fit frictionally and to turn therewith. The adjacent end of the bar 51 is centrally bored to provide a bearing for the left-hand end of the arbor which is cylindrical except at the extreme end where its tapers. Preferably the bearing is formed in a separate piece 54 which is screwed into a tapped recess in the body of the bar 51. The arbor has near its tapered end a shoulder 55 against which the grinding wheel is held by means of a sleeve 56 and nut 57. Between the shoulder 55 and end of spindle 50 is a nut 58 which serves to draw the arbor out of the tapered hole.

It will be observed that the grinding wheel is as nearly as possible midway between the heads 38 and 39 so that there may be room on each side of it for the work to travel entirely past, but that the bar 51 extends less than half way between the bearings and terminates some distance away from the grinder. This construction gives the maximum rigidity and is one of the most important features of my invention, since it prevents any deflection of the tool under the ordinary conditions of work, except that which is almost inappreciable. The rigidity thus given is due to the fact that the stationary bar can be made much thicker than the rotary spindle, its diameter being only limited by the internal diameter of the work and the amount of feed necessary to be given thereto, while the rotary spindle is limited in size by the necessity of conducting away the frictional heat generated by its rapid rotation. It is obvious that the latter is stiffened by having its outer end supported in a stationary bearing, since the bar 51 being shorter and of greater diameter than the spindle, is necessarily stiffer. The stiffness of this bar also increases in proportion as its length diminishes, and also the lateral force applied to the bar by the arbor diminishes in proportion as the bearing point of the arbor is more remote from the grinding wheel. This is due to the fact that the rotating spindle and arbor together may be considered as a beam supported at one end by the bearing 39 and at the other by the bar 51. The load is applied at the grinding wheel and is the pressure against the latter caused by the work being pressed against it. This load is supported by the end supports of the spindle, being divided between them, and the proportion borne by the bar 51 is less when its point of support of the arbor is remote from the grinder than when it is near the latter. Consequently within certain limits, the stiffness of the compound spindle increases as the stationary member diminishes in length. However, the tendency of the arbor to bend is increased as it is lengthened, and as this point of support grows more remote from the grinder. Consequently the increase of stiffness in the bar 51 due to moving the point of support away from the grinder, is partially compensated by the diminution of stiffness in the arbor, and therefore there is a point where these tendencies balance and where the maximum stiffness is obtained. The proportions whereby the maximum stiffness is secured are illustrated in Fig. 3, in which the stationary bar is short enough and its bearing with the arbor is remote enough from the wheel to give a relatively large stiffness, while the arbor is not given so great a length as to be weakened. The extended bearing of the arbor in the stationary member also adds to the stiffness, as does the sleeve 56 which is clamped on the outside by the nut 57. The latter has on its face next the stationary bar a flange which extends over an annular rib and prevents water and grit working between the bearing surfaces.

The live spindle is further stiffened by a bearing sleeve 59 which is rigidly bolted to the side of the inner head 39.

It will be noted that each of the members 50 and 51 has a long bearing in the boxes 49. The length of each box is comparatively great, while the total length of spindle contained in the two bearings is a very large proportion of the whole member, being as much as, or more than, half. This enables the spindles to be held without looseness so that the free end of the rotating one will turn accurately about its own axis, and not about a point outside of the axis. Each bearing box is a conical sleeve which is contained in a tapered recess in the head and is held securely therein by nuts 60 and 61, which are threaded upon the ends of the boxes and bear against opposite sides of the heads. Each box is centrally bored and is cut or split on one side from its outer periphery to the bore so that it can be compressed about the spindle by screwing up on the nut 60, and thus looseness may be taken up to the required degree, or the spindle may be clamped so firmly as not to be able to rotate. Each head has an oil hole 62 which passes through it and discharges into the slot 63 which divides the box (see Fig. 5).

In Fig. 3 the left-hand or stationary member of the spindle is contained in boxes which have only a slightly greater diameter than its own thickness, and is clamped tightly thereby so as to be incapable of rotation. The right-hand or live spindle, however, is of much smaller diameter, and the boxes in which it is contained rotatably are of an external diameter from three to five times as great as the spindle. The boxes are made of a composition in which copper largely predominates, such as brass or bronze. The boxes are made of this material and of this comparatively great size and mass in order that the frictional heat developed by the rapidly-rotating spindle may be absorbed and conducted away without producing enough expansion to cause the spindle to stick. With the usual iron bearings lined with soft metal, the spindle could not be rotated at such a high speed as is possible with the arrangement above described unless the bearings were adjusted so loosely as to give considerable back-lash, and thus impair the accuracy with which the spindle runs. I consider this feature of great importance in attaining the objects of accuracy and rapid work, because the qualities which the massive bronze bearings have of absorbing the heat enable larger and stiffer spindles to be used, and to be run at a high speed without appreciable back-lash, and thus the opportunity for deflection and looseness of the grinder at the point of application is reduced to the minimum.

Each of the heads is independently adjustable on its respective slide, and may be entirely removed therefrom so that each member of the spindle may be contained in only one bearing if desired, and the heads of either bearing may be adjusted toward or from each other to the necessary extent so as to contain in the two bearings as great a length of spindle as is desired for rigidity and strength. Between the bearings is a split pulley 64 which is clamped upon the live spindle by screws 65 (shown in Fig. 9) and is provided with hubs 66 which turn in recesses left for them in the adjacent nuts 60 and 61. These hubs enable the pulley to be retained in place while one spindle is removed and another substituted, this substitution being permitted by loosening the screws 65. The outer box may also be entirely removed from the slide so as to enable a driving belt 67 to be slipped over the pulley.

Another construction which eliminates looseness and back-lash is shown in Fig. 8 in which the slides 46 and 47 are shown as extending toward each other approximately as far as the members 50 and 51 respectively. Thus the pressure of the work against the grinding tool produces no more leverage on the slides through the spindles than would be the case if the tool were directly fastened to the slides. Consequently there is no opportunity of multiplying at the tool any looseness which may exist between the slides and the guide 48.

The left-hand slide 46 which carries the stationary spindle member is provided with a rack 68 with which meshes a pinion 69, held in a bearing beside the guideway 48 and connected with a hand wheel 70 by which it may be turned. By this means the member 51 may be moved away from the arbor 52 to permit placing of the work, and may then be carried through the work until the arbor is seated in its bearing. The movable slide is arrested when carried forward into correct position by an adjustable stop-screw 71 set into a lug 72 on a plate 73 which is fast to the outer end of slide 46 and overhangs the end of the guide. This is so adjusted that the slide will be stopped as soon as the tapered end of the arbor reaches the tapered portion of the bearing in block 54. After the machine has been running the arbor is inclined to become heated and to expand. In some constructions, to take care of this expansion, I make the bearing block 54 capable of yielding, as shown in Fig. 15. Here the block is contained in a recess in the end of the bar 51 in which it is capable of sliding endwise, being pressed outward toward the end thereof by a spring 74 which reacts against an adjustable abutment 75. The bearing piece is prevented from being expelled from the bar by a cap 76 threaded outside the latter and having a central orifice to receive the arbor. In both Fig. 3 and Fig. 15 the space in the bar 51 in rear of the bearing block is filled with fibrous absorbent packing 77 which is saturated with oil to lubricate the bearing. The supply of oil is replenished by a hole in the side of the bar, which is closed by a screw 78.

An important feature of this invention which conduces to the accurate results desired is the construction of the guideway 48. This is made upon two arms 79 and 80 which extend from opposite sides of a curved head or goose-neck 81 fixed to the pedestal 1. These arms are made tubular for stiffness, and the left-hand one which carries the endwise-movable slide is braced by a bracket 82 extending laterally from the pedestal, and a strut 83. As appears most clearly in Figs. 1, 5 and 9, the guide 48 is formed with the ordinary flat bearing face 84, and with undercut sides 85 and 86, but the novel feature consists in the fact that the broad face 84 is inclined downward toward the bed at an angle of approximately forty-five degrees. The upper edge 87 joining the face 84 and undercut side 85, is horizontal and parallel with the bed, and forms the actual guide for the slides. The latter are shaped so as to embrace the undercut sides, and each contains between one of its lips and the lower surface 86 an adjustable gib 88 which can be clamped against the guide in the usual manner to hold the slide stationary. The weight of the heads causes the slide to bear against the faces 84 and 85 simultaneously, and takes up any looseness which there might be between the lips of the slide and the undercut sides of the guideway. Thus the adjustment of the slides always takes place accurately upon a straight line which is that of the edge 87, and therefore the spindles are always held in exact alinement, whether the slides are clamped to the guides or are loose. Thus there is no possibility of the spindle axes getting out of line, even by carelessness and lack of attention on the part of the operator.

Instead of having a single tool act throughout the whole extent of the work piece, it is possible to grind the latter simultaneously at different points on two different diameters, as shown in Fig. 7. For this purpose the stationary rigid bar 51 is removed and a live spindle 89 substituted therefor which is held rotatively in a substitute set of boxes. These substitute boxes bear the same relation to the spindle 89 as the right-hand boxes to the spindle 50, for the purpose hereinbefore described. Upon the spindle 89 is clamped a split pulley 90 which is constructed in all parts the same as the pulley 64. It is driven by a belt 91 passing over a long drum 92 (Figs. 1 and 2) that is fixed to a counter-shaft 93 turning in bearings in a frame 94 which is pivoted to the column 81, and is adjusted so as to produce the proper tension of the belt by a bar 95 passing through the frame on which are screwed nuts 96. The drum has a length as great as the reciprocating motion given to the slide 46 and heads 38 so that the belt may continue to run upon it when the slide is retracted for insertion and removal of work. The counter-shaft 93 is driven at the desired speed by a cone pulley 97 to which a belt transmits motion from a convenient source of power. The right-hand end of spindle 89 which projects so that it may enter the work, is surrounded by a bearing sleeve 98 so as to be held rigid. This sleeve is the same in construction as the sleeve 59 shown in Fig. 3, except that it may be threaded upon the end of one of the boxes, as well as being secured by bolts 99 to the head, while the bearing sleeve 59 has a cylindrical flange 100 which is slipped outside of the left-hand nut 60 and is secured to the head 39 only by the bolts 101. On the end of spindle 89 is a grinding wheel

102 which is mounted directly upon the spindle and is held against a shoulder thereon by a nut 103. This same arrangement is provided for holding the wheel 37 instead of the arbor shown in Fig. 3.

Each of the grinding tools is fed automatically after each cut, and this feed may be the same in amount for each of the tools or it may be more rapid for one than for the other, according as conditions require. The feed is produced by a feed screw 104 of which there is one carried between the members of each pair of heads and rotatably mounted in a bearing 105 in a plate or feed box 106 which extends across the front of the heads of each pair, and is connected to them. The screw engages with a nut 107 formed upon a yoke 108 which extends across and is fastened to the rigid adjacent guideways 41. This yoke has two foot pieces 109, each of which passes through a slot in one of the slides 40 and is screwed to the guideway 41. The length of the slots through which the feet pass is enough greater than the feet to permit sufficient movement of the slides to give the necessary feeding movement to the tools. Flanges 110 surround the feet 109 and overlie the slots so that nothing can fall into them and obstruct the movement of the slides and heads.

On the forward end of each screw is fixed a ratchet wheel 111, while adjacent thereto is located a pawl 112 carried by an arm 113 pivotally secured at 114 in the feed box 106 (see Fig. 10). A spring 114 normally holds the arm and pawl elevated, while a spring-pressed pin 115 holds the toe of the pawl against the toothed periphery of the ratchet wheel. A bar 116 is arranged in the feed box below the ratchet wheel so as to reciprocate endwise in a direction parallel to the bed, and its ends protrude from the opposite sides of the box sufficiently to be engaged by feed dogs 117 and 118 carried by the upper bed or platen 8. Each dog carries an adjustable stop 119 which are adapted to engage opposite ends of the bar 116 alternately as the bed reciprocates, this engagement coming only near the end of the bed's travel and after the tool or tools have finished a cut. Movement of the bar causes a V-shaped cam protuberance 120 to be moved first to one side and then the other of a lug 121 attached to the pawl carrier 113. As one of the inclined sides of the protuberance is always in contact with the lug or an anti-friction ball 122 in the end of the latter, by reason of the action of spring 114, its travel causes the arm 113 and therewith the pawl to be lowered and raised, turning the ratchet wheel and feed screw one step. In order to regulate the distance through which the feed screw is turned, I provide a pointed set screw 123 which is threaded through the cover 124 of the feed box and bears at one side of its pointed end upon a beveled portion 125 on the edge of the arm 113. As will be understood from Figs. 9 and 10, a greater or less advancement of the set screw into the feed box will cause the arm to be lowered or raised respectively, and thereby diminish or increase the distance through which it may be moved by the cam projection 120. A similar set screw 126 (Figs. 1 and 2) has a pointed end similarly engaging a bevel 127 on the pawl 112 to regulate the distance of the latter from the ratchet wheel, and so to govern the length of time during which it will remain in contact with a tooth while being moved. By adjusting these screws, the wheel may be fed only one tooth at each operation, or as many teeth as desired up to as great a distance as the grinding wheel and work will stand.

The description above given applies equally to the left-hand feeding mechanism as to the right. For operating the former a pair of dogs 128 and 129 is provided. It will be seen that either feeding mechanism can be adjusted independently of the other so that one tool may be given a closer fit than the other if desired.

In order to eliminate looseness and backlash in the feeding screw, and so make the machine as nearly accurate as possible, I have provided a number of holes in the nuts 107 into each of which is forced a plug 130 of soft metal, such as babbitt, while set screws 131 are threaded into the holes and bear against the soft metal. By screwing down on the set screws, the Babbitt metal may be forced into the threads of the feed screw and between the latter and the nut, so that there will be no room left for endwise play.

The guideways 41 on which the slides 40 of the tool-carrying heads are fed are horizontal, and the heads are located vertically so the axes of the tools will lie at exactly the same level as the axis of the work. Thus the feeding movement of the tools takes place in the same plane as that in which their axes lie, so that the wearing away of the tool, and cutting of the work does not shift the point of contact with relation to this plane. If the tool were either above or below the center of the work and moved horizontally, the point of contact at which the cutting takes place would not be in the plane of the axes and would shift to a still greater distance from this plane as the work and tool became worn and cut away. This shifting of the point of contact causes the work to be inaccurate, making the finished bore of the work oval or elliptical, instead of truly circular. By having the tool fed directly toward the point at which the cutting takes place, the wear remains always in the line of feed, and so there is no opportunity for shifting of the point of contact and impairing the accuracy of the work. This is another feature which adds to the capacity of the machine for doing accurate work.

The heads of each pair are alined horizontally by the feed boxes 106 which are faced off flat on their rear sides and bear against the similarly faced flat forward surfaces of the heads. When screwed or bolted firmly to the heads, the feed-boxes cause the axes of the bearings to lie exactly in the same vertical plane. The heads are meanwhile adjusted vertically so as to bring the bearings into the same horizontal plane by plates 132 bolted to the upper flat faces of the heads, and of the upwardly-projecting flanges 400 of the slides 40. These surfaces are so located that when brought into the same plane, the axes of the bearings are alined. The heads are further secured by screws 1320 passing through slots 133 in the flanges 400 and entering tapped holes in the heads.

One of the greatest difficulties in performing accurate work is that the grinding wheel becomes glazed by the small particles of abraded metal filling the interstices of the wheel. The glazing does not take place evenly all over the wheel, and so those portions which are glazed slip over the work without cutting or being worn, while points diametrically opposite on the wheel cut the work and become worn away. This causes the tool to act unevenly, cutting away some parts of the work more than others, and being sprung more or less badly out of line, resulting in producing inaccurate results.

A part of my invention consists in providing a truing tool which cleans and faces off the grinder after each cut. This tool consists of a diamond embedded in the end of a shank 134 which is threaded into a holder 135 adjustably held on the top of one of the bearings for the work-holding chuck by a clamp screw 136. The holder is so arranged that the end of the shank projects over one end of the work piece close to the periphery of the grinder. As the work is moved so as to cause the grinder to emerge therefrom, the diamond point travels over the face of the latter and scrapes off a thin film from the cutting surface, removing the metal particles and breaking the bits of abrasive material so that they will present sharp corners and edges. Preferably the truing tool is adjusted before each emergence of the grinder so that it will face off the latter after each cut. To this end the shank 134 is provided with a feed wheel 137 having teeth which are brought at each movement of the work-holder up into engagement with a stationary pawl 138 mounted upon the nearest head. This pawl causes the wheel to be turned through the angular space of one or more teeth, according to the position of holder 135, and thereby advances the diamond point toward the surface of the grinder. The amount of the feed is adjusted so as only to take off enough material to keep the grinder truly cylindrical and clean on its surface. This truing tool forms part of the machine, and is operative during the required working movements thereof without necessitating any adjustment or re-arrangement of the tool relatively to the work, but acting while the same are in their proper relative positions for grinding. Where two grinders are employed the truing tools and holders therefor are duplicated, as shown in Fig. 7.

As before stated, the work-holding bed is mounted to reciprocate on guides 5 and 6. These latter are specially constructed for strength where they project beyond the sides of the pedestal 1, as shown in Fig. 9. The under side of each of the arms on which the guides are formed is cored out so as to provide vertical ribs 139 and 140 which are connected together by a transverse horizontal web 141. This maximum stiffness is secured without superfluity of metal, and a stiffer structure is obtained than if the arms were of solid metal, because there is no great weight in the arms themselves tending to cause deflection.

The lower bed or table has secured to it a rack 142 in one side of which is a groove 143 that is entered by a tongue 144 (see Fig. 1) to prevent the table being lifted from the guides. A pinion 145 (Figs. 1 and 14) meshes with the rack and gives the reciprocating movement to the bed which carries the work past the grinder. This pinion is driven alternately in opposite directions by a shaft 146, which in turn is driven by a cone pulley 147, and carries a worm 148 meshing with a worm wheel 149 on a transverse shaft 150. The latter has secured to it a bevel gear 151 engaging on opposite sides of its periphery two complemental gears 152 and 153 respectively, which rotate loosely. These bevel gears are rigidly attached to clutch members 154 and 155 respectively, by being driven upon and firmly engaged with the hubs 156 of the latter. These hubs turn loosely about a sleeve or tubular shaft 157 to which the hub of pinion 145 is secured by a pin 158. This pin also passes through a rod 159 which is movable endwise within the tubular shaft 157. A slot 160 in the rod permits the endwise movement but prevents any relative rotation between it and the tubular shaft. The endwise movement enables a clutch member 161 which is pinned to the rod and has clutch teeth on its opposite faces to be brought into engagement either with the clutch 154 or 155. As these latter clutches are constantly rotated in opposite directions, it will be seen that connection of the shiftable clutch 161 with each in turn will cause the pinion to drive first one way and then the other, reciprocating the bed and work.

The clutch is shifted by the movement of the bed 7 which carries on its forward edge adjustable dogs 162 and 163 on opposite sides of a lever 164 projecting upwardly close to the bed, and on the arm 164 is a roll 165 (Fig. 11) entering a groove in a longitudinally-reciprocable bar 166 pivotally connected at 167 to a bell-crank lever 168 that carries a roll 169 between adjustable stops 170 and 171 on the threaded end of rod 159. From Fig. 14 the action of the bar 166 in shifting the clutch will be obvious.

It is possible also to shift the clutch by hand. For this purpose a bar 172 having a quick thread, is secured to the lever 168 and projects forward through the frame of the machine. A stop in the form of a slide or nut 173 is mounted upon the thread of the bar 172, being provided with a handle 174 by which it may be turned, and having a flange 175 with a plane surface adapted to be forced against the flat front face of the frame. When this flange is screwed up against the frame, as in Fig. 14, the lever 168 is held in mid-position with the clutch 161 disengaged from both the members 154 and 155. On releasing the nut and swinging the bar 172 toward the right or left, the bed may be driven in either direction. This nut serves as a convenient and ready means for stopping the movement of the work instantly. Other types of stop slides may obviously be employed instead of the nut. The feed dogs are pivoted to holders 176 and 177 adjustably secured to the table 7 by headed bolts entering a groove 178 in the edge of the latter. By swinging the dogs upward about their pivots they may be caused to travel past the arm 164 without operating the same and reversing the feed.

The carriage 2 on which the beds are held, is mounted similarly to the cross-feed carriage in my prior patent above referred to, and is fed transversely of the bed and grinder by means of a screw 179 which is arranged and acts similarly to that in the patent referred to. The screw is turned step by step after each cut of the grinder so as to feed the work up to the latter, by a V-shaped cam projection 180 carried by the shiftable bar 166 (Fig. 11). The inclined sides of this cam projection act upon the end of a plunger 181 which passes downward through a sleeve 182 formed upon the stationary frame, and is held up against the cam projection by a spring 183. The plunger acts upon a pawl-carrying arm 184 so as to lower and raise a pawl 185 which bears against the periphery of a ratchet wheel 186 on a sleeve 187 carrying a pinion 188 that meshes with a gear wheel 189 fixed to the shank of the feed screw 179. The parts are so arranged that a downward movement of the plunger causes the pawl to move the ratchet 186 through a space of one or more teeth, according to the adjustment of the feed mehanism, while the pawl is raised after each downward movement by a spring 190 engaged with the arm 184 and with a bracket 191 to which the latter is pivoted. One adjustment for the feed is provided by the set screw 192 threaded into an arm of the bracket 191 which arrests the upward movement of the pawl and so limits its movement in that direction, while another set screw or screw stop 193 on the end of the arm 184 bears against the plunger 181 and by adjustment limits the distance by which the latter moves the pawl downward. A third screw 194 having a pointed end engages the edge of the pawl nearest the ratchet, and so regulates the proportion of its travel in which it remains in contact with the ratchet. A spring 195 holds the pawl against this screw and against the ratchet. The smallest adjustment possible is one tooth of the ratchet, and the pitch of the feed screw and value of the gear train may be made such that each tooth will feed the work a distance of one ten-thousandth of an inch. The feeding devices previously described for moving the grinders may also be designed for a like fineness of adjustment, but a still finer feed may be designed if desired.

A convenient construction for automatically stopping the cross feed when the work has been finished approximately to the required size has been provided in the shield 196 which projects over the ratchet and is fastened to a disk 197 mounted loosely upon the sleeve 187 beside the ratchet 186. A clamp nut 198 threaded upon the sleeve serves to bind the disk in adjusted position and may itself be held by a set-screw 199. After the grinding operation has been started, and a measurement taken, the shield may be set at a distance from the toe of the pawl 185 corresponding to the exact number of ten-thousandths of an inch of stock still to be removed. This distance is determined by a scale of graduations 200 marked on the ratchet. It will be understood after the disk has been clamped to the ratchet, it turns therewith, and when the lower edge of the shield comes adjacent the lower limit of the pawl's movement, the latter will simply slide upon the shield, and will cease to feed the work further.

It will be seen that the feeding mechanism last described, and the two feeding devices for the tool or tools, provide separately-operable means for feeding either the work or the grinder relatively to the other, each of which may be used alone, or all of which may be used in combination. Where a single tool is mounted as shown in Fig. 3, it is sometimes convenient to hold the same in one position while the work is fed toward it, while when two tools are used, the work may be held stationary and each tool separately fed. Or, on the other hand, the tool feed and work feed may be used in combination and in opposite directions so that the grinder may be fed as fast as its surface is removed by the truing tool so as to keep the acting point in the same position while the work feed produces the necessary alteration of position of the latter. Again, by causing the tool to be fed in the same direction as the work, but at a slower rate, the difference between the two feeds may be made to produce a finer feed than can be obtained by either that of the work or tool alone, and thereby work of great accuracy may be brought forth.

Cooling water is conducted to the work by a pipe 201, and discharged from a nozzle 202 into the bore of the work. Flowing thence the water falls upon the beds and is collected in a trough 203 on the rear side of the latter, whence overflowing it falls into a trough 204 and into wide shallow pans 205 and 206 on the rear of the carriage 4. The overflow water from these pans is collected and pumped again through the supply pipe by constructions and means similar to those described in my prior Patent No. 790,099 above referred to.

I claim:—

1. A grinder for internal work comprising a work-support adapted to hold a hollow piece, a holder for a grinding wheel passing through the work piece and stationary rigid bearings for said holder, said bearings being of a diameter less than the wheel, projecting toward one another and adapted to enter the work.

2. A grinder for internal work comprising a work-support adapted to hold a hollow piece, and a holder for a grinding wheel passing entirely through the work and supported at each end at a greater distance from the grinding wheel than the length of the work, said holder including a rotary spindle and a rigid, laterally extending bar adapted to pass into the work and having a bearing for the spindle.

3. A grinding machine comprising a bed, a work support adapted to hold work mounted on said bed so as to be movable thereon, a guide parallel with said bed, a slide movably held on said guide, a bracket secured to said slide and overhanging the bed laterally, a second bracket also overhanging the bed, and a grinder spindle held by said brackets, said slide permitting movement of the bracket supported thereby when struck by the work support.

4. A grinding machine comprising a bed, a work support adapted to hold work mounted on said bed so as to be movable thereon, brackets mounted beside said bed and arranged to project laterally over the same in substantial alinement with the work, and a grinder spindle supported at its ends by said brackets and extending perpendicularly to the direction of overhang of the latter.

5. In a grinding machine for internal work, a bed, bearings separately secured upon said bed, a work-holding sleeve having a central passage extending throughout its entire length, means carried by said sleeve for clamping tubular work pieces centrally therein, and centering devices detachably mounted upon the foot or base portions of said bearings and movable axially thereof, said centering devices having cones located coaxially with said sleeve adapted to enter the ends of the work and locate the same centrally with respect to the sleeve and said clamping means.

6. In a grinding machine, separated supports, and a three-part holder for the grinder extending between said supports, said holder consisting of a spindle rotatably mounted in one of said supports, a bar clamped in the other support so as to project therefrom toward said spindle, and an arbor attached to said spindle and having a bearing in the end of said bar.

7. In a grinding machine, separated supports, a three part holder for the grinder extending between said supports and held thereby, and a grinding wheel carried and rotated by said holder at a point substantially midway between said supports.

8. In a grinding machine, a grinding wheel spindle consisting of a stationary member free at one end, a rigid holder therefor, a rotary member abutting against said stationary member and held against deflection thereby, a support in which the latter member is rotatably mounted, and a grinding wheel carried by said rotary member.

9. In a grinding machine, a grinding wheel spindle consisting of a stationary member free at one end, a rigid holder therefor, a rotary member having a bearing within the end of said stationary member, whereby it is held from deflection, a support for the latter member, wherein the same is rotatably mounted, and a grinder carried by said rotary member, said grinder having a greater amount of lateral projection from the axis of rotation than either member of the spindle.

10. In a grinding machine for internal work, a spindle consisting of rotary and non-rotary members in line adapted to pass through the work, a projection from the end of one of said members having a bearing in the adjacent end of the other mem-

ber, a grinding wheel carried by the rotary member, and means for rotating said member.

11. In a grinding machine for internal work, a spindle consisting of rotary and non-rotary members in line adapted to pass through the work, a projection from the end of one of said members having a bearing in the adjacent end of the other member, a grinding wheel carried by the rotary member, means for rotating said member, and means for separating said members to permit placing of the work.

12. In a grinding machine adapted for internal work, a plurality of separated supports, a spindle rotatably mounted in one of said supports, a bar or shaft held rigidly by the other of said supports, said spindle and bar extending toward each other and each adapted to pass through the work, and an arbor held in the end of the spindle so as to rotate therewith and having a bearing in the end of the bar.

13. In a grinding machine adapted for internal work, a plurality of separated supports, a spindle rotatably mounted in one of said supports, a bar or shaft held rigidly by the other of said supports, said spindle and bar extending toward each other and each adapted to pass through the work, and an arbor held in the end of the spindle so as to rotate therewith and having a bearing in the end of the bar, said arbor having provisions for holding a grinder adjacent the spindle and relatively remote from the bar.

14. In a grinding machine adapted for internal work, a plurality of separated supports, a spindle rotatably mounted in one of said supports, a bar or shaft held rigidly by the other of said supports, said bar being relatively thick and of a length less than half the distance between the supports, and an arbor attached to the spindle so as to rotate therewith and having provisions for securing a grinder closely adjacent the end thereof, and bearing at its other end rotatively in the end of the bar.

15. In a grinding machine, a rotary spindle, a supporting bearing therefor, a grinding tool carried by said spindle at a distance from said bearing, and a stationary support extending toward said spindle, wherein the latter has a bearing at a point remote from the tool.

16. In a grinding machine, a rotary spindle, a supporting bearing therefor, a tool-holding arbor secured to the end of said spindle so as to rotate therewith, having provisions for securing a tool near its point of attachment to the spindle and having a bearing portion remote from the tool and on the opposite side of the latter from the spindle, and a support extending toward the spindle, providing a bearing for the arbor.

17. In a grinding machine for internal work, a rotary spindle, a supporting bearing therefor, a tool-holding arbor secured to the end of said spindle so as to rotate therewith, being tapered at one end for that purpose and cylindrical adjacent its other end for bearing rotatively in a fixed support, and having a shoulder for positioning a grinding tool, a sleeve adapted to be secured on the arbor to clamp the tool against said shoulder, and a support extending toward the spindle, providing a bearing for said cylindrical portion of the arbor.

18. In a grinding machine for internal work, a rotary spindle, a supporting bearing therefor, a tool-holding arbor secured to the end of said spindle so as to rotate therewith, being tapered at one end for that purpose, having provisions for securing a tool near its point of attachment to the spindle and having a bearing portion remote from the tool and on the opposite side of the latter from the spindle, a nut threaded on said arbor adjacent the tapered end thereof for disconnecting the same from the spindle, and a support extending toward the spindle, providing a bearing for the arbor.

19. In a grinding machine for internal work, a rotary spindle, a supporting bearing therefor, a tool-holding arbor secured to the end of said spindle so as to rotate therewith, having provisions for securing a tool near its point of attachment to the spindle and having a bearing portion remote from the tool and on the opposite side of the latter from the spindle, a sleeve adapted to be secured on the arbor to clamp the tool against said provisions, a nut threaded on the arbor to secure said sleeve and having on its outer face a flange to overlap the bearing, and a support extending toward the spindle, providing a bearing for the arbor.

20. In a grinding machine, a spindle adapted to carry a grinding tool, means for rotating the spindle at a high velocity and two bearings in which the spindle is rotatably contained, each independently adjustable to take up looseness, said spindle extending to one side from said bearings and having provisions for carrying the tool at its end.

21. In a grinding machine, a spindle adapted to carry a grinding tool at one end, means for rotating the spindle at a high velocity, and bearings in which the other end of the spindle is rotatably held, the part of the spindle contained in said bearings being relatively great in proportion to the entire length of the spindle.

22. A grinding machine including a work-support, a tool support, and a guide

on which said support is slidably mounted, said guide being at an angle to the horizontal and having one edge, which extends in the direction of travel of the support, raised above the rest of the guide, whereby said tool support is automatically clamped in any position on the guide by gravity.

23. In a grinding machine, a guide having a flat face at an angle with respect to the horizontal, whereby one of the edges of said guide, which is horizontal and extends in the direction of travel of the tool holder, is located at a higher elevation than any other part of said face, and a tool holder slidingly mounted on said guide, bearing on the flat face thereof and clamped by gravity against the raised edge.

24. In a grinding machine, a guide having a flat face and undercut sides, arranged at an angle with respect to the horizontal, whereby one of the edges of the guide is raised above the other parts thereof, and a tool holder mounted to slide on said guide and having portions embracing the undercut sides thereof, said tool holder being caused by gravity to be automatically clamped against the raised side of the guide and to be guided with absolute exactness by the edge thereof, which edge extends in the direction of travel of the tool holder.

25. In a grinding machine, a bed for supporting the work, a guide having an inclined flat face and undercut sides, and a tool-supporting bracket overhanging the bed and supported by the guide so as to slide thereon in a direction at right angles to the slant of said inclined face, said bracket having portions embracing the sides of the guide and being held by gravity firmly against the inclined flat face and the upper side thereof.

26. In a grinding machine, a tool-supporting guide having an upper horizontal guiding edge and a bearing face extending downwardly from said edge.

27. In a grinding machine, a pair of guides extending in line oppositely from the central plane of the machine, each having a downwardly extending bearing face and an upper guiding edge, and a tool-holding support mounted to slide on each of said guides and held by gravity against the upper edge thereof.

28. In a grinding machine, a pair of guides extending in line oppositely from the central plane of the machine, each having a face angularly disposed with respect to the horizontal and an upper guiding edge, a tool-holding support mounted to slide on each of said guides and held by gravity against the upper edges thereof, and rack and pinion mechanism for reciprocating one of said supports on its guide.

29. In a grinding machine, a bed, work-supporting means including separable bearings adapted to be clamped on the bed, and independently movable toward and from one another, and a sleeve rotatably mounted in said bearings, having provisions for securing the work co-axially therewith.

30. In a grinding machine, a bed, and a work-support consisting of a sleeve having a central passage extending throughout its length, adapted to receive the work, means carried by the sleeve for clamping the work centrally therein, and a plurality of bearings adapted to be secured to the bed in any one of a variety of positions, and in which said sleeve is rotatably held.

31. In a grinding machine, a bed, and a work-support, including separate bearings adapted to be moved together and apart and to be independently secured to the bed, a sleeve contained in said bearings, and collars on the sleeve adjacent the outer sides of the bearings, said collars having clamps for securing the work centrally therein.

32. In a grinding machine, a work-holding bed, a holder adapted to carry a hollow work piece, a head overhanging the bed and having a bearing, a grinding tool spindle rotatably mounted in said bearing and supported thereby so as to extend over the bed and enter the work piece with its axis in the same horizontal plane as the axis of the work, and means for feeding the tool holder and tool horizontally.

33. In a grinding machine, a work-holding bed, a head overhanging the bed and having a bearing, a grinding tool spindle rotatably mounted in said bearing, and a support of said head on which the same is movably mounted and arranged to be fed transversely of the spindle in a plane parallel to that of the axes of the spindle and work, whereby the point of contact of the tool and work is at the same height as the former wears and the latter is cut away.

34. In a grinding machine, a work-supporting bed, a spindle-carrying head overhanging said bed, a spindle rotatably held in said head, and a grinder carried by said spindle, the head being adjustable vertically to bring the spindle axis to the level of the axis of the work, and being horizontally adjustable transversely of said axes to feed the tool toward the work.

35. In a grinding machine, a work-supporting bed, a spindle-carrying head overhanging said bed, a spindle rotatably held in said head, a grinder carried by said spindle, a rigid horizontal transverse guide, and a slide mounted thereon; said head being secured with provision for vertical adjustment to said slide.

36. In a grinding machine, a work-supporting bed, a spindle-carrying head overhanging said bed, a spindle rotatably held in said head, a grinder carried by said spindle, a rigid horizontal transverse guide, a

slide mounted movably thereon, to which said head is secured with provisions for vertical adjustment, said slide and head having flat upper surfaces, and a flat plate secured to the same for alining and maintaining the head at the required height above the bed.

37. In a grinding machine, a bed for supporting the work, grinder-spindle-carrying heads overhanging the bed, independent cross-feed slides to which said heads are connected, and a rigid yoke or connecting piece secured to said heads for holding them in alinement.

38. In a grinding machine, a bed for sup porting the work, grinder-spindle-carrying heads overhanging the bed, and having flat front faces, independent cross-feed slides to which said heads are connected, a rigid feed box having a flat rear face secured to said flat faces for holding the heads in alinement, and means carried by the feed box whereby said heads and slides may be moved step by step to feed the grinder.

39. In a grinding machine, the combination with a work-support and means for feeding the same longitudinally; of a transverse slide, a spindle-carrying head on said slide, a spindle rotatably contained in said head, and means operated by said longitudinal feeding means for feeding said slide step-by-step transversely.

40. In a grinding machine, the combination with a work-support and means for feeding the same longitudinally of a transverse slide, a spindle-carrying head on said slide, a spindle rotatably contained in said head, a feed screw for said slide to move the same transversely, and mechanism operated by the longitudinal feeding means for rotating said screw step-by-step.

41. In a grinding machine, the combination with a work-support and means for feeding the same longitudinally of a transverse slide, a spindle-carrying head on said slide, a spindle rotatably contained in said head, a feed screw for moving the slide transversely, a ratchet connected thereto, and a pawl actuated by the longitudinal feeding means for turning the ratchet and screw intermittently.

42. In a grinding machine, the combination with a work-support and means for feeding the same longitudinally of a transverse slide, a spindle-carrying head on said slide, a spindle rotatably contained in said head, a feed screw for moving the slide transversely, a ratchet connected thereto, a pawl arranged to engage the teeth of the ratchet, and dogs moved with the work-support for intermittently actuating said pawl to turn the ratchet and feed screw step-by-step.

43. In a grinding machine, the combination with a work-support and means for feeding the same longitudinally of a transverse slide, a spindle-carrying head on said slide, a spindle rotatably contained in said head, a feed screw for moving the slide transversely, a ratchet connected thereto, a pawl arranged to engage the teeth of the ratchet, an arm to which said pawl is connected, a cam member for swinging said arm to actuate the pawl, and devices operated by the longitudinal feeding means for so actuating said cam.

44. In a machine of the character described, a grinding tool, a spindle for the same, a head in which the spindle is rotatably mounted, a transverse guideway on which the head is adapted to slide; and a cross-feed for the same, including a screw engaged with said guideway and carried by the head, a ratchet on said screw, a pivoted pawl carrier, a pawl thereon for actuating said ratchet, and an endwise movable bar having a protuberance arranged to engage said pawl carrier and operate the pawl.

45. In a machine of the character described, a grinding tool, a spindle for the same, a head in which the spindle is rotatably mounted, a transverse guideway on which the head is adapted to slide; and a cross feed for the same, including a screw engaged with said guideway and carried by the head, a ratchet on said screw, a pivoted pawl carrier, a pawl thereon for actuating said ratchet, an endwise movable bar having a protuberance arranged to engage said pawl carrier and operate the pawl, and a spring acting on said pawl-carrier to hold the same in position to be engaged by the protuberance of said bar.

46. In a grinding machine, a plurality of cross-slide guides, a slide mounted on each guide, a head secured to each slide, bearings in said heads, a grinder spindle rotatably mounted in said bearings, a yoke fastened to said guides having a nut, a yoke fastened to said heads, and a feed screw carried by said second yoke engaged with said nut.

47. In a grinding machine, a plurality of cross-slide guides, a slide mounted on each guide, a head secured to each slide, bearings in said heads, a grinder spindle rotatably mounted in said bearings, a yoke fastened to said guides having a nut, a yoke or feed box having an integral bearing fastened to said heads, and a feed screw held in said bearings and threaded into said nut.

48. In a grinding machine, a head having a bearing, a grinder spindle rotatably held in said bearing, a transverse guide on which said head is enabled to slide to feed the grinder, a nut secured to said guide, a screw carried by said head in threaded engagement with the nut, a mass of soft material in said nut in contact with said screw, and means for compressing said material against the screw to take up backlash thereof.

49. In a grinding machine, a head having

a bearing, a grinder spindle rotatably held in said bearing, a transverse guide on which said head is enabled to slide to feed the grinder, a nut secured to said guide, a screw carried by said head in threaded engagement with the nut, said nut having one or more tapped passages opening into its threaded bore, a quantity of soft metal in said passage, and a set screw in said passage for forcing the soft metal against the screw to take up backlash thereof.

50. In a grinding machine, a work-supporting bed, arms having guides beside and above said bed, and a plurality of tool-holding heads or brackets mounted to slide parallel to the bed on said guides.

51. In a grinding machine, a work-supporting bed, arms having guides beside and above said bed, and a plurality of slides mounted on said guides, heads or brackets secured to said slides, and grinder-holding bars or shafts carried by said heads and projecting therefrom to permit entrance into a hollow work piece, each slide projecting approximately as far beyond said brackets as the bar or shaft attached thereto and being substantially coterminous therewith, whereby the bars or shafts are held rigidly and looseness at their free ends avoided.

52. In a machine of the character described, a base, a curved column rising from said base, and guides extending in alinement on opposite sides of the column and supported thereby, said guides being adapted to hold one, or a plurality, of tool holders.

53. In a machine of the character described, a support and tubular arms or beams extending horizontally from said support, said arms or beams having guiding surfaces for tool holders.

54. In a machine of the character described, a support, and tubular arms or beams extending horizontally from said support, said arms or beams having each a dove-tail guide portion extending downward from one edge thereof, and a bracket for supporting a tool mounted to slide horizontally on said dove-tail portion with a base embracing the edges thereof, and a gib carried by the bracket base beside the lower side of said guide adapted to be clamped against the same.

55. In a grinding machine, a work-supporting bed, a guide substantially parallel thereto, a plurality of heads or brackets movably held on said guide, bearings in said heads, a grinder spindle rotatable in said bearings, and a split pulley surrounding said spindle between said heads, having a hub contained in bearings therein.

56. In a grinding machine, a work-supporting bed, a guide substantially parallel thereto, a plurality of heads or brackets movably held on said guide, bearings in said heads, a grinder spindle rotatable in said bearings, and a pulley on said spindle confined between said heads; either of the heads being removable from the guide to permit of placing or removing a belt.

57. In a grinding machine, a work-supporting bed, a guide substantially parallel thereto, a plurality of heads or brackets movably held on said guide, bearings in said heads, a grinder spindle rotatable in said bearings, a connection between said heads whereby they are held at a uniform distance apart and caused to move together on the guide, a pulley on the spindle between the heads, a belt passing over said pulley, and a driving drum parallel to the guide, over which the belt passes, whereby movement of the heads is permitted without removal of the belt.

58. In a grinding machine, a work-supporting bed, a guide, a holder mounted on said guide movable thereon to permit placing of the work, a grinder spindle contained rotatably in said holder, a pulley thereon, a driving drum parallel to said guide and of as great length as the normal range of travel of the holder thereon, and a belt surrounding said driving drum and pulley.

59. In a grinding machine, a work-supporting bed, a guide, a holder mounted on said guide movable thereon to permit placing of the work, a grinder spindle contained rotatably in said holder, and a stop for limiting the movement of said holder on said guide toward the work.

60. In a grinding machine, a work-supporting bed, a guide, a holder mounted on said guide movable thereon to permit placing of the work, a grinder spindle contained rotatably in said holder, and a stop on the outer end of the holder overlying the end of the guide, for limiting the movement of said holder on said guide toward the work.

61. A grinding machine, comprising in combination a stationary support, bearings secured to said support for holding a rotary grinder spindle, a spindle adapted to carry a grinder rotarily contained in said bearings, a work-holder, means for producing a relative longitudinal feeding movement between the same and the grinder, means for feeding the work-holder transversely toward the grinder as stock is removed from the work, and means for feeding the spindle and grinder as the latter becomes reduced in diameter.

62. A grinding machine, comprising in combination a stationary support, a grinding tool and spindle therefor, a work-support adapted to be moved parallel with the axis of said tool and spindle, a transverse slide on which the work-support is mounted and whereon it is movable to bring the work up to the grinder as stock is removed, transverse guides secured to said stationary sup-

port, separate heads for holding and supporting said spindle mounted movably on said guides, feeding means for each of said slides, and devices carried by said work-support for operating each of the feeding means.

63. A grinding machine, comprising in combination a stationary support, guides fixed thereto, separated tool-holding heads or brackets mounted to slide on said guides, supports for a grinding tool extending from said heads toward each other, a work-holding bed mounted to travel longitudinally of said tool supports, mechanism for so moving the bed reciprocally, a transverse slide on which said bed is held, independent feeding mechanisms for the heads and slide, and devices carried by the bed for operating each of said feeding mechanisms.

64. A grinding machine, comprising in combination, a stationary support, a tool spindle rotatably held in bearings in said support, a grinding tool attached to said spindle, a bed adapted to support the work, a carriage on which said bed is mounted to reciprocate, said carriage being movable transversely of the direction of reciprocation of the bed, a feed screw for moving the carriage, pawl and ratchet mechanism for turning said screw intermittently, means operated by the bed for driving said pawl and ratchet mechanism, and a shield adapted to overlie part of the teeth of the ratchet for limiting the amount of feed thereof.

65. A grinding machine, comprising in combination, a stationary support, a tool spindle rotatably held in bearings in said support, a grinding tool attached to said spindle, a bed adapted to support the work, a carriage on which said bed is mounted to reciprocate, said carriage being movable transversely of the direction of reciprocation of the bed, a feed screw for moving the carriage, pawl and ratchet mechanism for turning said screw intermittently, means for driving the bed, including oppositely rotating clutch members and an intermediate driven clutch member engageable alternately with the driving members, a reciprocable rod connected with said driven clutch member for shifting the same, said rod having a cam protuberance for actuating said pawl and ratchet mechanism, and dogs carried by the bed for reciprocating said rod, whereby the bed-driving mechanism is reversed and the carriage simultaneously fed.

66. A grinding machine, comprising in combination, a stationary support, a tool spindle rotatably held in bearings in said support, a grinding tool attached to said spindle, a reciprocable bed and a shiftable clutch member for driving the bed alternately in opposite directions, a lever connected for shifting said clutch member, and a stop slide on said lever adjustable to hold the same in a neutral position with the clutch member inoperative.

67. In a grinding machine having a frame, a reciprocable bed, oppositely moving driving clutch members and a shiftable driven clutch member for driving the bed alternately in opposite directions, a lever connected for shifting said clutch member, projecting externally of the frame, and a stop on said lever adapted to be pressed against the frame to hold the lever in a neutral position with the driven clutch member disengaged from both the driving members.

68. In a grinding machine having a frame, a reciprocable bed, oppositely moving driving clutch members and a shiftable driven clutch member for driving the bed alternately in opposite directions, a lever connected for shifting said clutch member projecting externally of the frame, and a nut on said lever, and a handle on said nut, whereby the latter may be clamped against the frame to hold the lever and driven clutch member in an intermediate and inoperative position, adapted to operate said lever to connect the driven member with either driving member.

69. In a grinding machine, a standard, a carriage mounted thereon with provision for cross-feeding movement, ways formed on said carriage extending transversely of the direction of movement of the carriage and projecting beyond the ends thereof, and each supported by a plurality of separated integral vertical ribs and a work-supporting bed arranged to travel on said ways.

70. In a grinding machine, a standard, a carriage mounted thereon with provision for cross-feeding movement, having arms extending transversely to the direction of feed of the carriage and separated vertical supporting ribs beneath said arms cast integral therewith and with the body of the carriage, said arms forming guideways, there being a plurality of ribs under each guide-way and a bed mounted to travel on said guideways.

71. In a grinding machine, means for rotating a grinding wheel and preventing deflection thereof, consisting of separate spindle members extending toward each other, one of which is rotary, separated supports by which the remote ends of said members are supported, a wheel-carrying arbor secured to the rotating member, and a bearing block carried by the other member having a bearing for the end of said arbor, said block being mounted to yield so as to permit elongation of the arbor.

72. A grinding machine, comprising in combination, a stationary support, a grinding tool and spindle therefor, a work-support adapted to be moved parallel with the

axis of said tool and spindle, a carriage on which said work-support is held, arranged to travel transversely of the direction of reciprocation of the work-support, mechanism for so reciprocating the work-support, and feeding means operated by the same mechanism for moving said carriage to bring the work up to the grinder as stock is removed.

73. A grinding machine, comprising in combination, a stationary support, a grinding tool and spindle therefor, a work-support adapted to be moved parallel with the axis of said tool and spindle, a bed mounted to reciprocate to which the work-support is secured, a carriage on which said bed is held, arranged to travel transversely of the direction of reciprocation of the bed, mechanism for so reciprocating the bed, feeding mechanism for moving the carriage to advance the work toward the grinder as stock is removed, and means carried by the bed for actuating said feeding mechanism.

74. A grinding machine, comprising in combination, a stationary support, bearings thereon, a tool spindle rotatably held in said bearings, a grinding wheel secured to said spindle, a work-support, a bed on which said work-support is adjustably secured, said bed being mounted to reciprocate, a carriage on which said bed is held, arranged to travel transversely of the axis of the grinding wheel, feeding mechanism for causing the carriage thus to travel to feed the work toward the grinder as stock is removed, and a single actuating mechanism for reciprocating the bed and operating the carriage feed.

75. A grinding machine, comprising in combination, a support, bearings thereon, a tool spindle rotatably held in said bearings, a grinding wheel secured to said spindle, a work-support, a bed on which one of said supports is adjustably secured, said bed being mounted to reciprocate parallel to the axis of said tool and spindle, a carriage on which said bed is held, arranged to travel transversely of the direction of reciprocation of the bed, mechanism for so reciprocating the bed, feeding mechanism for moving the carriage to effect a feed movement as stock is removed from the work, and dogs carried by the bed for reversing the direction of its own motion and operating the carriage feed.

76. A grinding machine, comprising in combination, a support, a tool spindle rotatably held in bearings in said support, a grinding tool attached to said spindle, a bed, a carriage on which said bed is mounted to reciprocate, said carriage being movable transversely of the direction of reciprocation of the bed and of the tool and spindle for effecting a feed movement as stock is removed from the work, a feed screw for moving the carriage, pawl and ratchet mechanism for turning said screw intermittently, and means operated by the bed for driving said pawl and ratchet mechanism.

77. A grinding machine, comprising in combination, a support, a tool spindle rotatably held in bearings in said support, a grinding tool attached to said spindle, a bed, a carriage on which said bed is mounted to reciprocate parallel to the axis of the tool and spindle, said carriage being movable transversely of the direction of reciprocation of the bed, a feed screw for moving the carriage, pawl and ratchet mechanism for turning said screw intermittently, a movable cam member and a spring for operating said pawl and ratchet mechanism, and dogs carried by the bed for moving said cam member.

78. A grinding machine, comprising in combination, a stationary support, a tool spindle rotatably held in bearings in said support, a grinding tool attached to said spindle, a bed adapted to support the work, a carriage on which said bed is mounted to reciprocate parallel to the axis of the tool and spindle, said carriage being movable transversely of the direction of reciprocation of the bed, a feed screw for moving the carriage, pawl and ratchet mechanism for turning said screw intermittently, an arm by which said pawl is carried, a reciprocable bar having a cam projection whereby to oscillate said arm, and dogs carried by the bed for reciprocating said bar.

79. In a grinding machine, a work support and means for rotating the same, a grinding wheel spindle, a holder for said spindle in which the latter is held parallel with the axis of rotation of said work support, a slide by which said holder is carried, and means independent of other moving parts of the machine for moving said slide, and therewith the grinder spindle, longitudinally toward and from the work support.

80. In a grinding machine, a work support and means for rotating the same, a grinding wheel spindle, a holder for said spindle in which the latter is held parallel with the axis of rotation of said work support, a slide by which said holder is carried, and a feed wheel having connection with said slide and independently operable to move the latter, and therewith the grinder spindle longitudinally toward and from the work support.

81. In a grinding machine, a work support and means for rotating the same, a grinding wheel spindle, a holder for said spindle in which the latter is held parallel with the axis of rotation of said work support, a slide by which said holder is carried, said slide having a set of rack teeth, a driving pinion meshing with said teeth, and a feed wheel secured to said pinion and independently operable to rotate the latter so as to move said slide and spindle longi-

tudinally toward and from the work support.

82. In a grinding machine, a work holder comprising a plurality of independent bearing brackets, a sleeve arranged to rotate about its own axis in said brackets, means on said sleeve for holding work pieces, and a rotary driving element secured to said sleeve between said bearing brackets.

83. In a grinding machine, a work holder comprising a sleeve having provisions for securing work pieces placed within it, a plurality of separate and independent bearings in which said sleeve is held in such manner that it may rotate therein about its own axis, and a pulley for rotating said sleeve secured thereto between the bearings.

84. In a grinding machine, a framework, consisting of a base or pedestal, a head or gooseneck secured to said pedestal, rising above and extending over the top thereof, and tubular arms extending in alinement oppositely from said head and being provided with a guideway extending continuously from the extreme end of one arm to the extreme end of the other.

85. A grinding machine comprising a base or pedestal, a carriage mounted on said base, a bed supported and movable in the direction of its length on said carriage, a horizontal guideway parallel to, and at a higher elevation than, said bed, a plurality of slides mounted on said guideway, and heads for rotatably supporting grinder spindles mounted on said slides and overhanging the bed.

86. A grinding machine comprising a base or pedestal, a carriage mounted on said base, a bed supported and movable in the direction of its length on said carriage, a horizontal guideway parallel to, and at a higher elevation than, said bed, a plurality of slides mounted on said guideway, and heads for rotatably supporting grinder spindles mounted on said slides and overhanging the bed, said guideway being continuous from end to end and of sufficient length to support one of the slides, and the supported head thereon, adjacent each end of the bed.

87. In a grinding machine, a framework, consisting of a base or pedestal, a guide extending horizontally over said pedestal, and supports for said guide mounted on the pedestal and holding the guide above the latter; a carriage supported on said pedestal beneath the guide, and means for feeding said carriage transversely of the guide.

88. In combination with a grinding machine for internal work, a work holder comprising slides having bearings, a sleeve mounted to rotate in the bearings of said slides and centering members secured upon said slides in axial alinement with said sleeve adapted to enter the ends of a tubular work piece to center the latter relatively to said sleeve.

89. In a grinding machine for internal work, a tubular, rotating work holder, means for rotating said work holder, and three equidistantly spaced clamps adjacent to each end of said holder for supporting a tubular piece of work therein.

In testimony whereof I have affixed my signature, in presence of two witnesses.

JOHN BATH.

Witnesses:
ARTHUR H. BROWN,
C. F. BROWN.