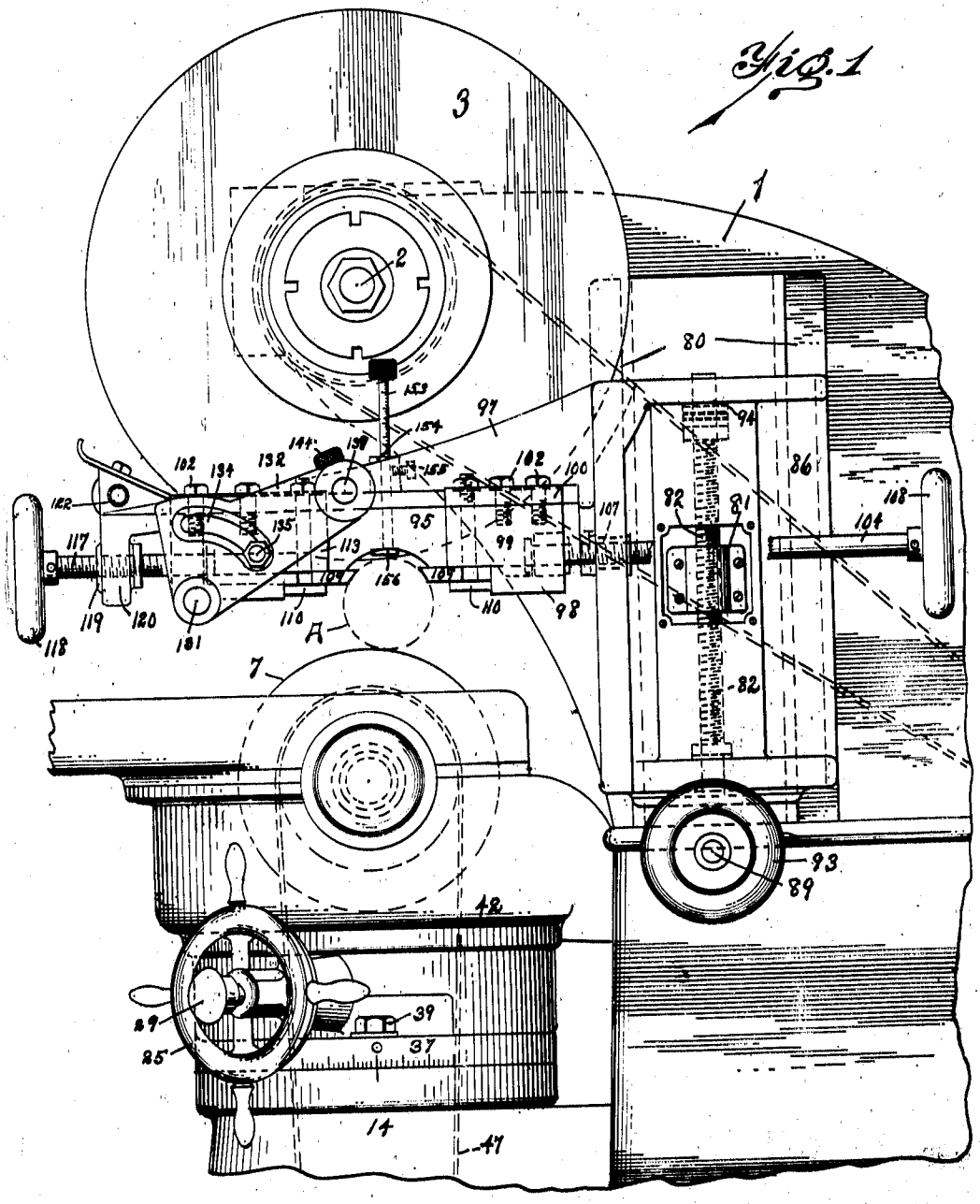
Oct. 22, 1929. E. SOBOLEWSKI 1,733,086

CENTERLESS GRINDER

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Fig. 1



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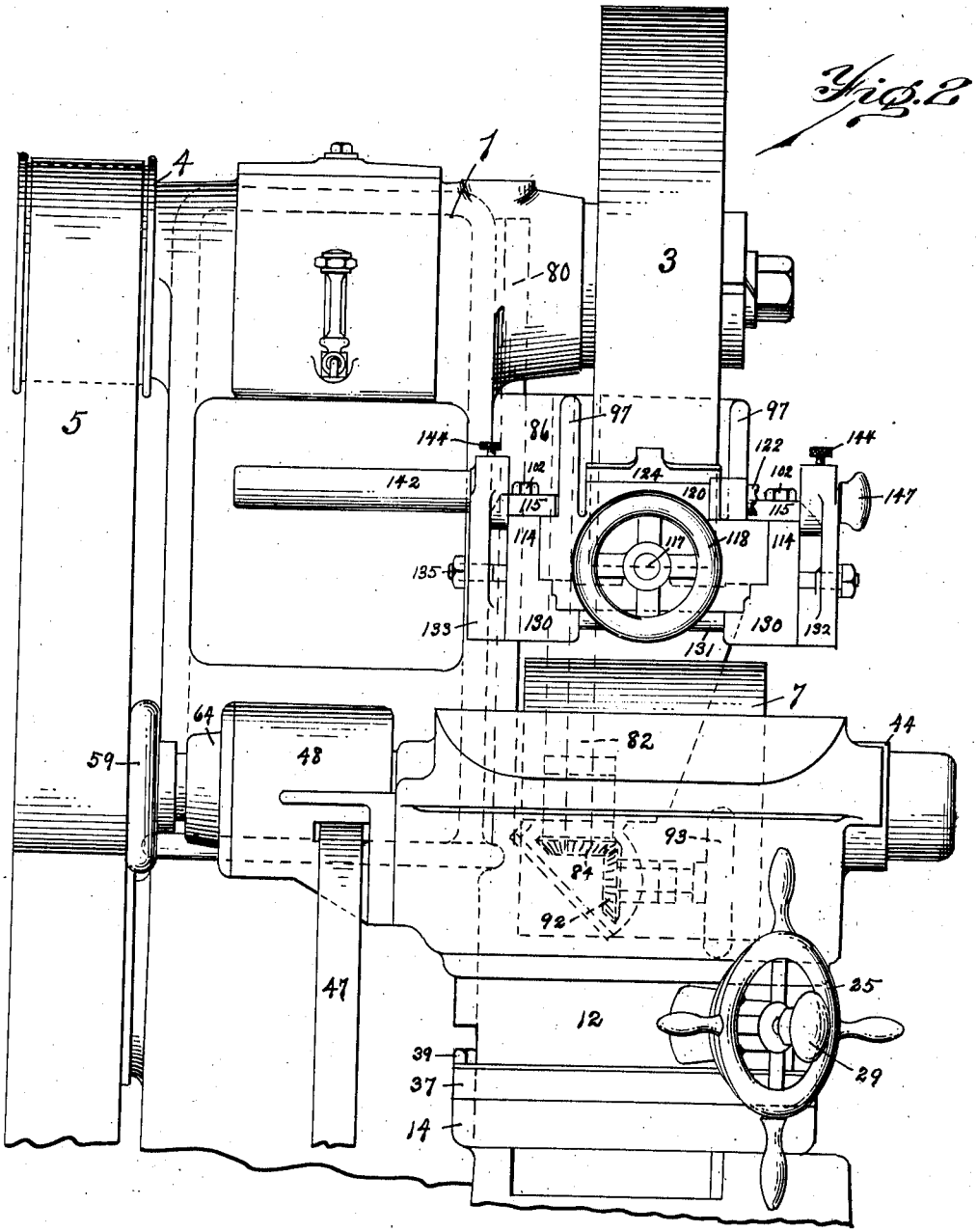
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CENTERLESS GRINDER

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Fig. 2



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CENTERLESS GRINDER

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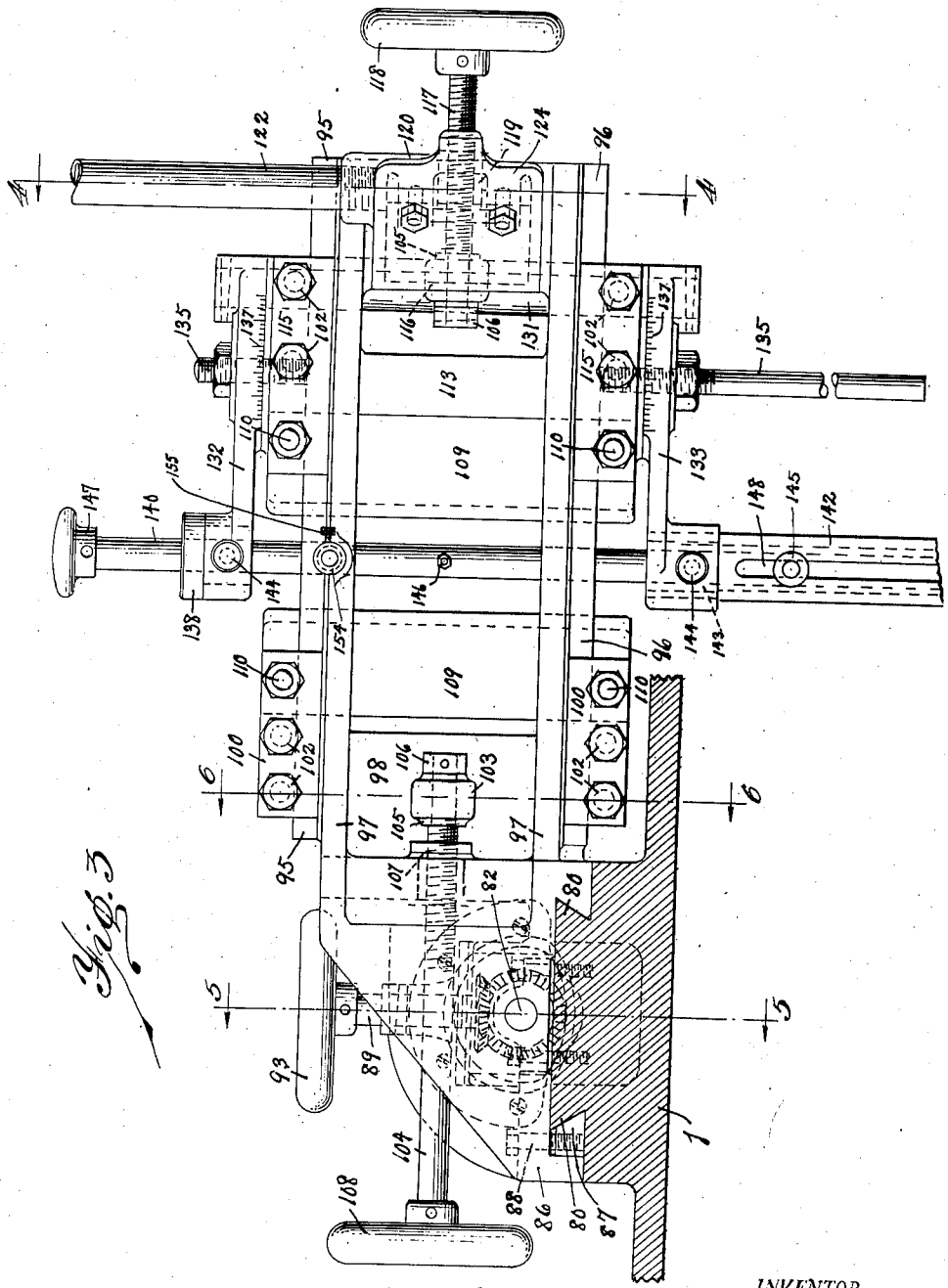


Fig. 3

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CENTERLESS GRINDER

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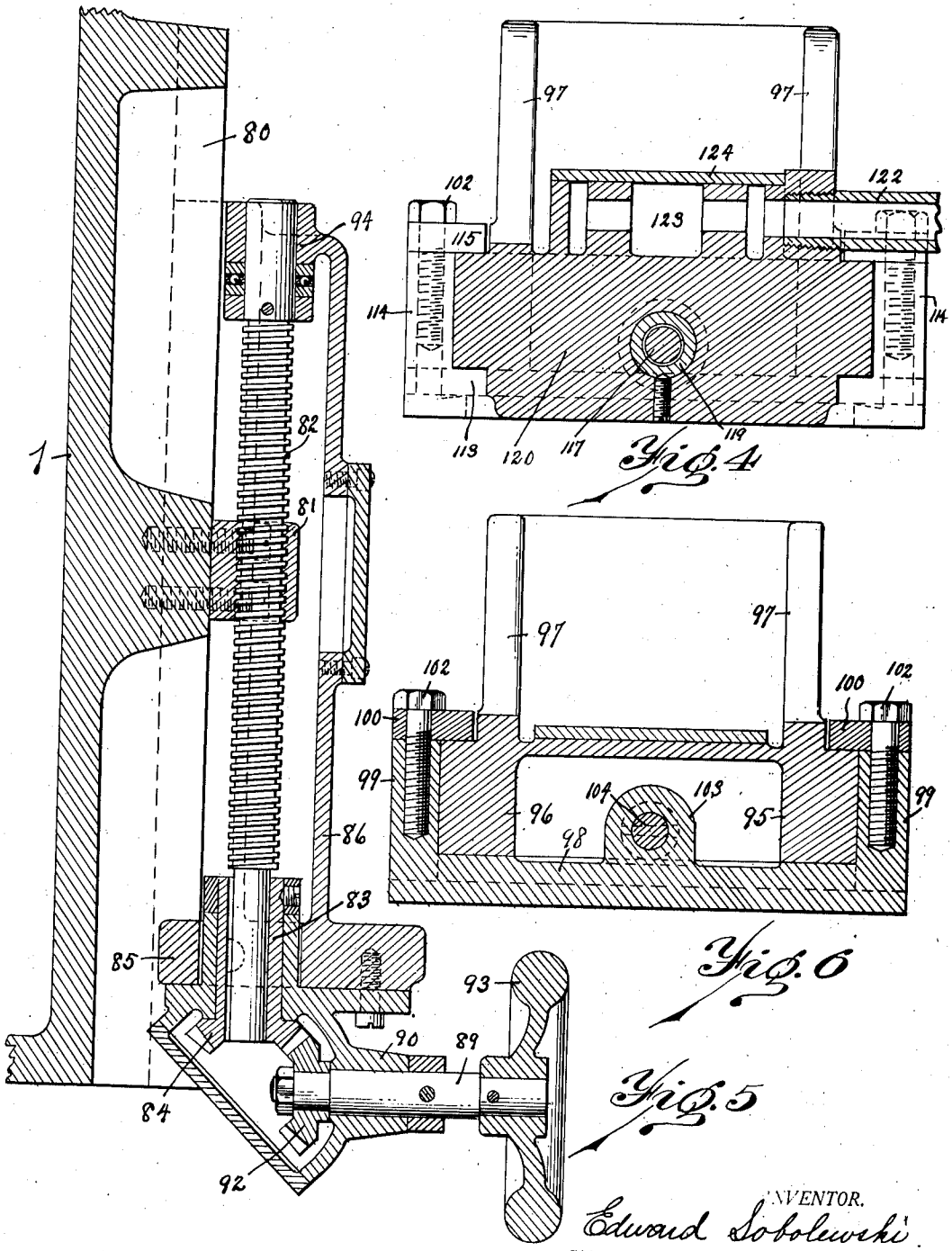


Fig. 4

Fig. 6

Fig. 5

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CENTERLESS GRINDER

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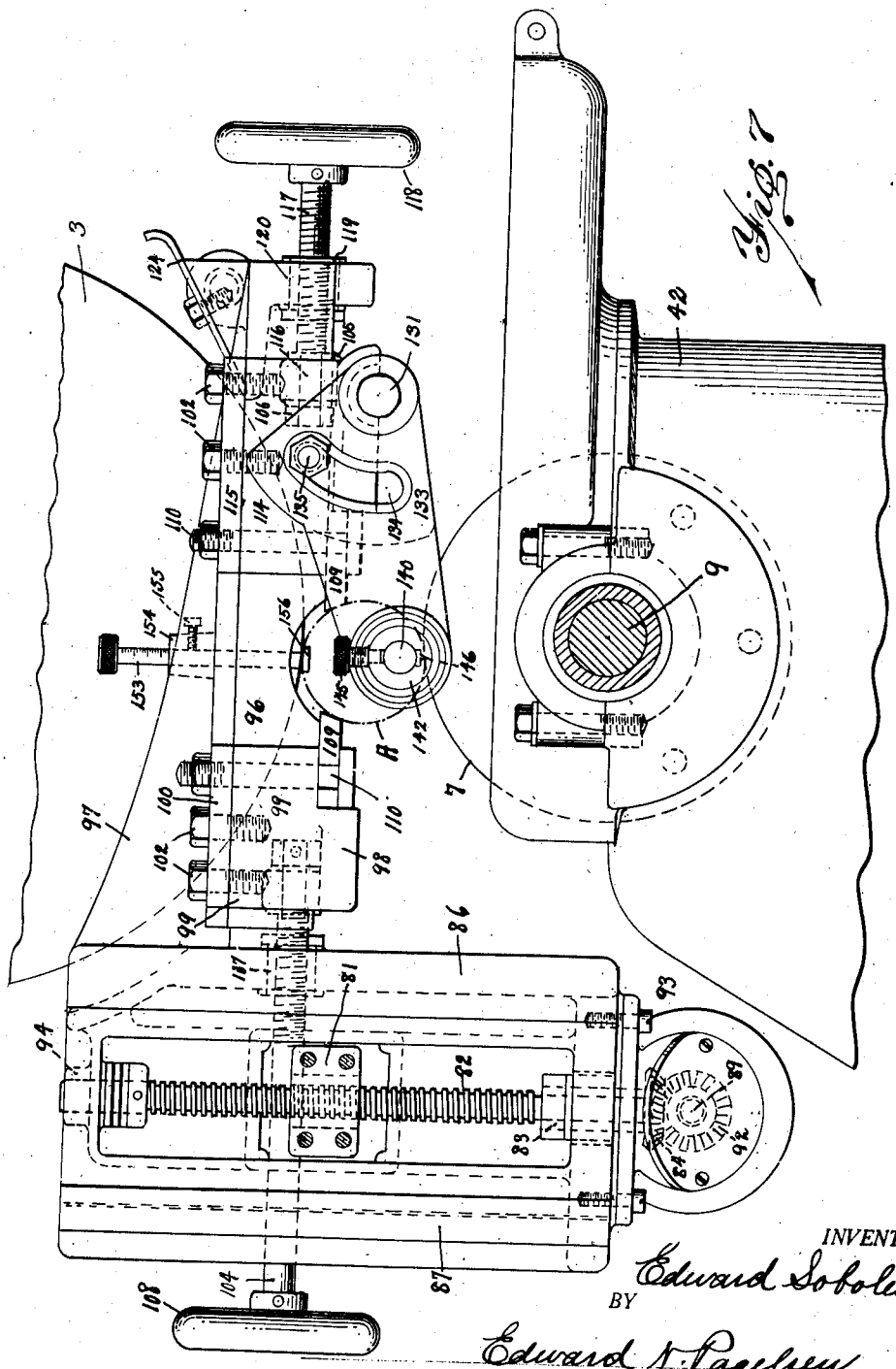


Fig. 7

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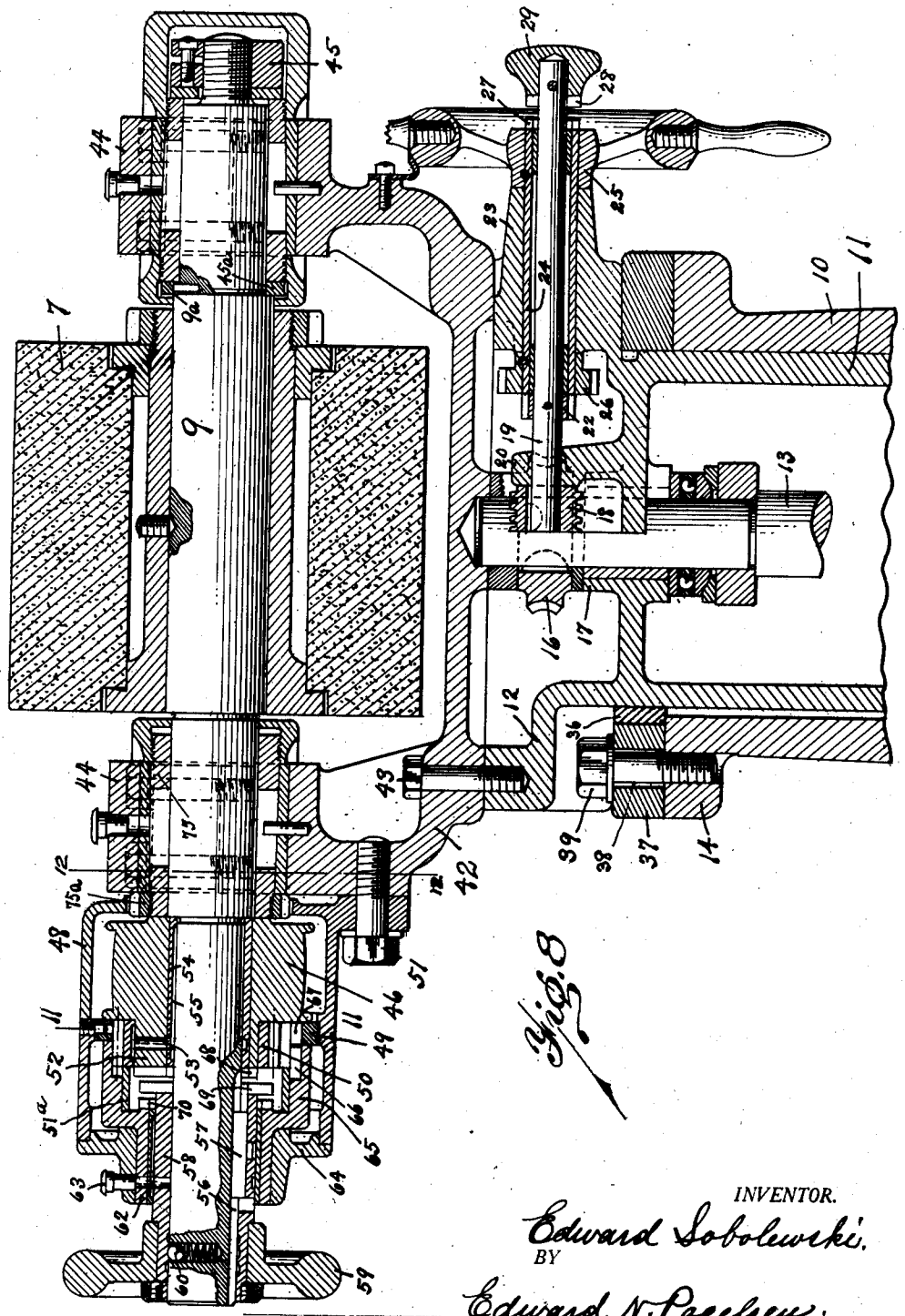


Fig. 8

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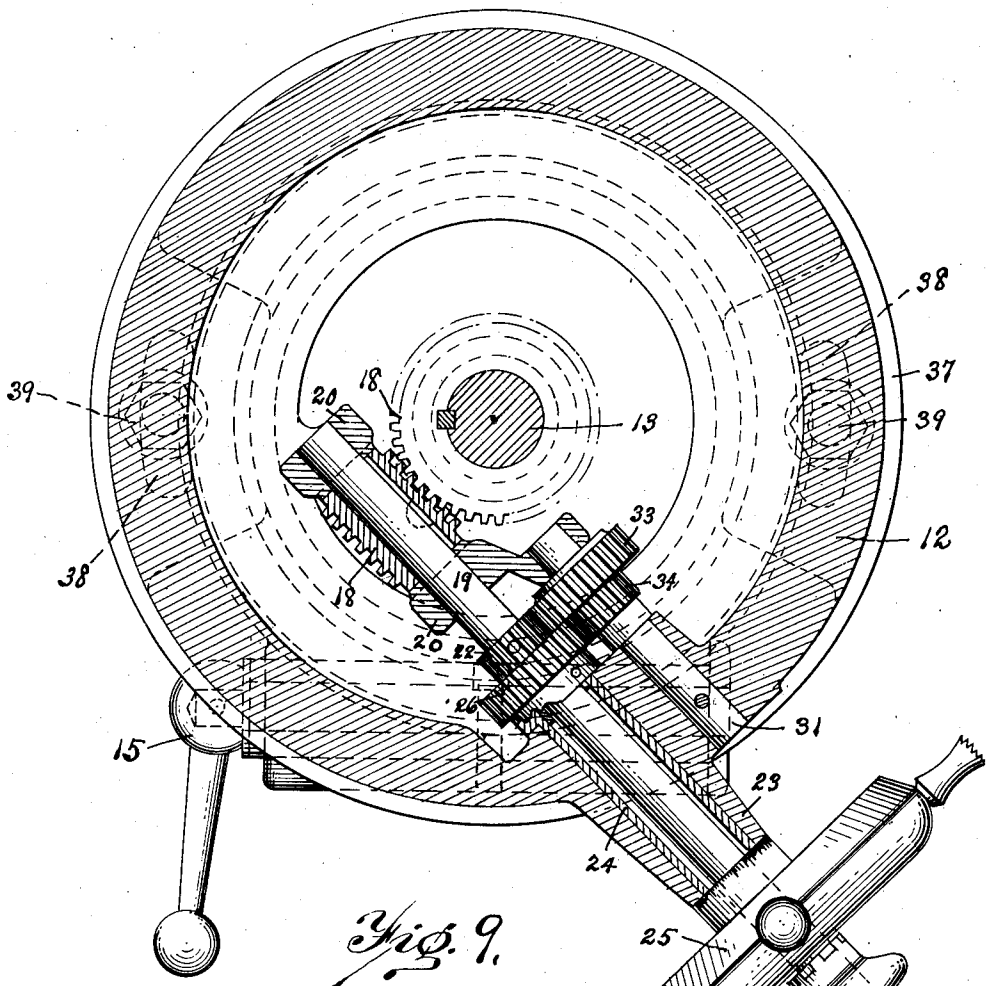


Fig. 9.

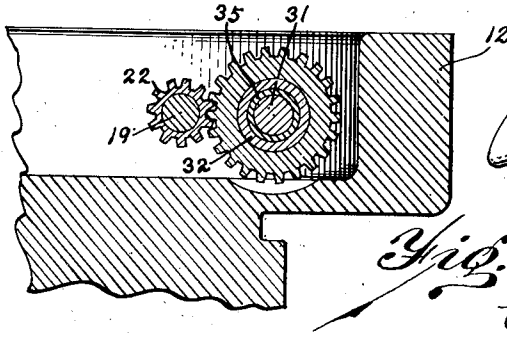


Fig. 10

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CENTERLESS GRINDER

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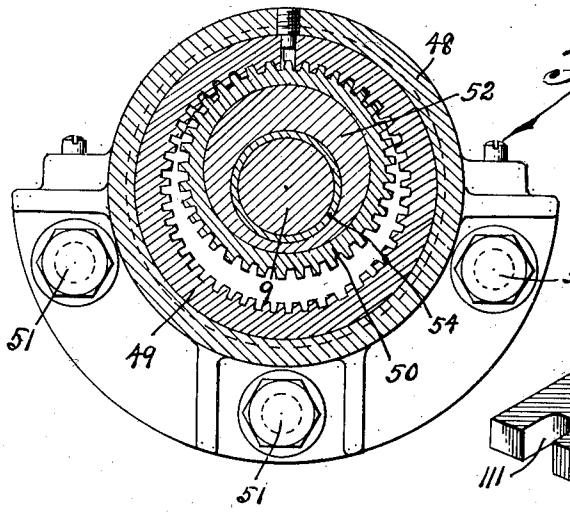


Fig. 11.

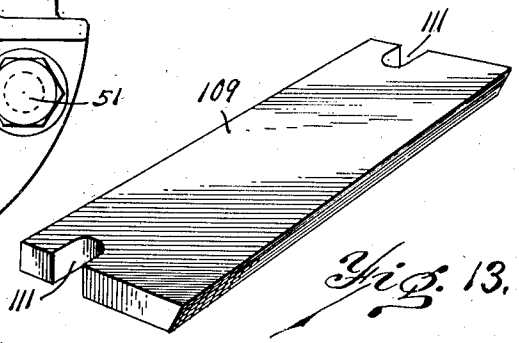


Fig. 13.

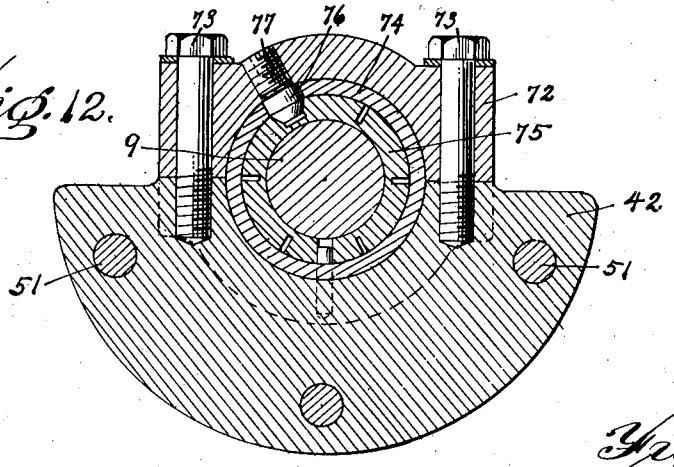
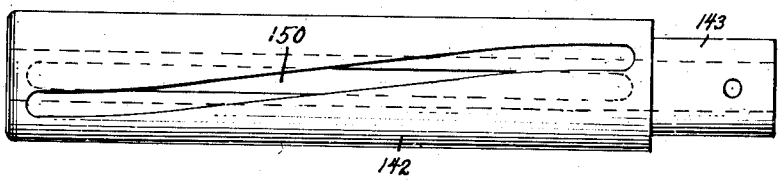


Fig. 12.

Fig. 14.



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Patented Oct. 22, 1929 1,733,086

UNITED STATES PATENT OFFICE

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CENTERLESS GRINDER

Application filed April 23, 1921. Serial No. 463,892.

This invention relates to grinding apparatus.

One of the objects of this invention is to provide a grinding apparatus of thoroughly rugged and practical construction, highly efficient action, and well adapted to meet certain peculiar conditions met with in practical use. Another object of this invention is to provide a grinding apparatus in which work pieces may be rapidly and with a high degree of precision ground to true round cross-section without necessitating the mounting of the work on centers, or the like, and to provide such a grinding apparatus in which control of the rotation of the work, while a grinding wheel performs a grinding operation thereon, is positive and uniform and may be made to take place, in accordance with certain preferred features of my invention, both before and after the grinding operation by the grinding wheel commences. Another object is to provide an apparatus of the above-mentioned character in which a work-rotation-controlling wheel is so positioned with respect to the grinding wheel, preferably underneath the grinding wheel, so as to achieve certain important actions contributed by the effect of gravity on the work. Another object of this invention is to provide a grinding apparatus of the above-mentioned character in which a feeding action by the work-rotation-controlling wheel may be dependably and reliably achieved, both before and after, as well as during, the grinding operation on the work by the grinding wheel. Another object, more specifically, is to provide a grinding apparatus in which the work-rotating wheel is of greater width of operative face than the grinding wheel so as to achieve certain important advantages in both the control of the rotation and axial feeding movement of the work, either before or after, or both before and after, the grinding operation on the work by the grinding wheel. Another object is to provide a grinding apparatus of the above-mentioned character in which the two wheels and related parts are so related to each other that the effect of gravity on the work may be dependably and efficiently utilized in insuring effective work-rotating contact and work-feeding contact between the work and the work-rotating wheel, particularly before and after the grinding operation on the work by the grinding wheel.

Another object is to provide a grinding machine of the above-mentioned character in which rotation and feed of the work may be effectively achieved without depending upon the thrust of the grinding wheel for urging and holding the work in effective operative contact with the work-rotating and feed wheel. Another object is to provide an apparatus of the above-mentioned character in which rotation of the work prior to its entry into contact with the grinding wheel, and also after leaving contact with the grinding wheel, may be dependably achieved in a simple and thoroughly practical manner. Another object is to provide a construction of the above-mentioned character in which starting of the rotation of the work by the work-rotating wheel may be achieved without depending upon the grinding wheel to force the work into work-rotating contact with the work-rotating wheel, so that the work-rotating wheel already has control of the rotation of the work before the latter contacts with the grinding wheel.

Another object of this invention is to provide a compact and practical driving arrangement for the work-rotating wheel well adapted for simple and rapid manual control to give the work-rotating wheel the necessary very slow speed for controlling the rotation and feed of the work or for giving the work-rotating wheel a relatively much higher speed when it is desired to true the wheel. Another object is to provide apparatus of the above-mentioned character in which control of the relative positions and relations of the two wheels may be manually effected in a thoroughly practical, simple and rapid manner. Another object is to provide a thoroughly practical and dependable means for holding work of round section between the grinding wheel and the work-rotating wheel while permitting axial movement

thereof, without necessitating the mounting of the work on centers or the like, and to provide a dependable and readily operable and convenient mechanism for predetermining the relation of the work-holding means to the work and to the wheels.

Another object is to provide a grinding apparatus in which the work-rotating and feed wheel is positioned below the grinding wheel and to provide rugged, efficient and dependable supporting, control, and drive arrangements for the two wheels, and to provide an apparatus having the work-rotating wheel positioned below the grinding wheel that will be well adapted to meet the varying conditions of hard practical use and well adapted for rapid, efficient and high precision grinding on a large scale. Other objects will be in part obvious or in part pointed out hereinafter.

The invention accordingly consists in the features of construction, combination of elements, and arrangements of parts as will be exemplified in the structure to be hereinafter described and the scope of the application of which will be indicated in the following claims.

In the accompanying drawings, in which is shown a preferred embodiment of this invention,

Figure 1 is a right side elevation of the grinding apparatus in assembled relation, the lower portion of the apparatus being omitted;

Figure 2 is an elevation as seen from the left of Figure 1;

Figure 3 is a plan view on an enlarged scale of the work-holding mechanism and certain of the control mechanism therefor, and of the wheel truing mechanism;

Figure 4 is a vertical sectional view on an enlarged scale taken along the line 4—4 of Figure 3;

Figure 5 is a vertical sectional view on an enlarged scale as taken along the line 5—5 of Figure 3;

Figure 6 is a vertical sectional view on an enlarged scale taken along the line 6—6 of Figure 3;

Figure 7 is a view, on an enlarged scale, as seen partially from the rear of Figure 1 of the work-holding mechanism, wheel truing mechanism, certain of the control mechanism therefor, the frame of the machine being understood to be removed;

Figure 8 is a vertical sectional view, on an enlarged scale, taken substantially through the axis of the lower or work-rotating and feed wheel, showing the mounting and support and control therefor of the work-rotating and feed wheel, and showing also the speed-change drive mechanism for the latter;

Figure 9 is a horizontal sectional view on an enlarged scale taken substantially through the horizontal axis of the hand wheel of Figure 8, showing certain details of the mechanism for raising and lowering the work-rotating and feed wheel;

Figure 10 is a detailed vertical sectional view taken along the line 10—10 of Figure 9;

Figures 11 and 12 are vertical sectional views taken along the lines 11—11 and 12—12 respectively of Figure 8;

Figure 13 is a perspective view of one of the work-holding members which hold the work between the two wheels, and

Figure 14 is an elevation of part of the wheel-truing mechanism.

Similar reference characters refer to similar parts throughout the several views of the drawings.

Referring now to the drawings and more particularly to Figures 1 and 2, there is provided a main frame 1, having a suitable horizontally extending base, only a portion of which is shown in the drawings, and having an upper portion extending to the left, as viewed in Figure 1. In this upper overhanging portion of the frame 1 there is supported in suitable bearings a spindle or arbor 2 carrying at one end thereof (the right-hand end, as viewed in Figure 2) a grinding wheel 3 and carrying at the other end thereof (the left-hand end, as viewed in Figure 2) a pulley 4 over which runs the driving belt 5, connected to any suitable source of power, for driving the grinding wheel at a suitable grinding speed.

As will be clear from Figures 1 and 2, there is positioned and rotatably supported underneath the grinding wheel 3 a wheel 7; one of the distinguishing features of this invention lies in the construction, relative arrangement, and drive of this wheel 7, and it may here be noted that the work A, interposed between the two wheels, will be seen to be physically supported on the wheel 7. The wheel 7 may be termed a work-supporting wheel, but in view of its primary function in controlling the rotation of the work A, all as hereinafter described in detail, I prefer to term it a work-rotating or regulating wheel. The wheel 7, preferably of abrasive material, is preferably of less diameter than the upper or grinding wheel 3 and in accordance with certain distinctive features of this invention, the regulating wheel 7 is made of sufficient length (axially, as viewed in Figure 2, and with respect to the width of the operative face of the grinding wheel 3) to support the work A before, during, and after coming into contact with the grinding wheel 3. According to another distinctive feature of this invention, as hereinafter made clear, the wheel 7, because of this relative dimension with respect to the grinding wheel face, also rotates the work positively and uniformly and effects an axial feeding movement

of the work before, during, and after the work is in contact with the grinding wheel 3.

The wheel 7 is preferably so positioned that its axis (assuming its axis and the axis of the peripheral grinding wheel 3 to be parallel) and the axis of the grinding wheel 3 are in the same vertical plane; this preferred relation is clearly shown in Figure 1. The work-rotating wheel 7, however, is mounted so that its spindle 9, together with the wheel 7, may be swung out of parallelism with the axis of the grinding wheel and, more particularly, so that the axis of the work-rotating wheel 7 will be at an appropriate but relatively small angle to the axis of the work A which is preferably held, by means more fully described below, so that the axis of the work A is substantially parallel to the axis of the peripherally operative grinding wheel 3. Preferably, also, the axes of the two wheels, where they operate by way of their peripheries, as is illustrated in the preferred embodiment shown in the drawings, are in horizontal planes. The above-described angular relation of the axis of the work-rotating wheel 7 to the axis of the work A achieves a feeding movement of the work A in an axial direction, as will be made more clear hereinafter.

Considering more in detail the mounting of the work-rotating wheel 7, it may first be noted that the base portion of the frame 1 has an upstanding hollow pedestal 10 (see Figure 8) positioned substantially underneath the grinding wheel 3; the pedestal 10 is bored out to receive a cylindrical ram 11 having a table 12 formed at its upper portion. To the table 12 is secured a frame 42 (Figure 8) by means of cap screws 43, the frame 42 being suitably formed to provide bearings 44 for rotatably supporting the spindle 9 which carries the wheel 7. A thrust collar 45 at the right-hand end of the spindle 9 and a collar 45^a coacting with shoulder 9^a on the spindle 9 coact to prevent endwise movement of the spindle 9 with respect to the bearing 44 in the frame 42. A pulley 46 (Figure 8) driven by a belt 47 (Figure 2) from any suitable source of power drives the spindle 9 and the wheel 7 but through mechanism, more clearly described hereinafter, whereby the wheel 7 is rotated comparatively slowly during the operation of the apparatus but at quite high speed while the wheel 7 is being dressed or trued.

The wheel 7 may be moved toward or away from the grinding wheel 3 by raising and lowering it, the ram 11 sliding vertically within the pedestal 10. A screw 13 (Figure 8) extends downwardly into a rigidly supported nut (not shown) carried in the base portion of the machine, and the upper portion of the screw 13 is so secured to the table 12 and ram 11 that the up or down movement of the screw 13 is communicated to these parts and the table 12, frame 42 and wheel 7 correspondingly elevated or lowered.

Secured to the upper end of the screw 13 is a worm wheel 16 (Figures 8 and 9), the upper end of the screw 13 being rotatably supported in the table 12 by means of a bearing 17. A worm 18 meshes with the worm wheel 16 and is carried by a shaft 19 which is rotatably and slidably supported in the bearings 20 (Figure 9) carried by the table 12. To the shaft 19 is also secured a gear 22 (Figures 8, 9 and 10).

The shaft 19 extends outwardly through the side of the table 12, the latter being formed with a tube-like extension 23 through which the shaft 19 passes. Interposed between the shaft 9 and the sleeve 23 and rotatable with respect to both is a sleeve 24. The right-hand end of sleeve 24 has secured thereto a graduated hand wheel 25 and its left-hand end, as viewed in both Figures 8 and 9, has secured thereto a gear 26. Gears 22 and 26 are positioned adjacent each other and will be seen to be coaxially mounted, gear 22 being rotatable with the shaft 19 and gear 26 being rotatable with the sleeve 24, the latter being rotated manually by the hand-wheel 25.

Adjacent and parallel to the shaft 19 there is rigidly supported within the peripheral wall portions of the table 12 a shaft 31 upon which is rotatably mounted a sleeve 32 to which gears 33 and 34, which mesh respectively with gears 22 and 26 (see Figure 9) are secured so as to rotate therewith as a unit. A bearing bushing 35 may be interposed between the sleeve 32 and the shaft 31 (Figure 10).

The outer or right-hand end of the sleeve 24 is formed with clutch teeth 27 (Figure 8) and at the outer end of the shaft 19, which, as above noted, is axially slidable, is secured a knob 29, the inner or left-hand end of which has formed thereon clutch teeth 28 adapted to interengage with the clutch teeth 27 when the knob 29 and the shaft 19 are moved to the left, as viewed in Figure 8, or to be disengaged therefrom, when the parts are in the position shown in Figure 8.

When it is desired to raise or lower the regulating wheel 7 so as to change the distance between the adjacent operative surfaces of the two wheels for accommodating work of different diameter, the movement of the wheel in a vertical direction may be effected rapidly by pulling the knob 29 toward the right, as viewed in Figures 8 and 9, thus to disengage the clutch 27—28; the resultant axial movement of the shaft 19 in a direction toward the right, moves the gear 22 into engagement with the gear 33. The subsequent manual rotation of the hand wheel 25 causes the rotation of the shaft 19 and of the worm 18 through gear 26, gear 34, gear 33, and gear 22, the ratios of drive of these gears being such as to greatly multiply or increase the speed of rotation of the shaft 19 and worm

18 with respect to the rate of rotation of the hand wheel 25. For example, the gear ratios may be such that the shaft 19 and worm 18 will be turned four times as fast as the hand wheel 25.

Thus, very rapid manual movement of the one wheel toward or away from the other may be effected.

However, when it is desired to make a fine and relatively precise adjustment of one wheel toward or away from the other, the knob 29 is pushed inwardly or to the left, as viewed in Figures 8 and 9, whereupon the clutch teeth 27 and 28 interengage and the gear 22 is moved to the left out of meshing engagement with the gear 33. The speed-increasing gearing is thus cut out of action and the shaft 19, through the clutch 27—28, is thus directly connected to the hand wheel 25; thus, the worm 18 may be directly rotated manually by the hand wheel 25, and due to the speed ratio between the worm 18 and the worm wheel 16, a far greater rotative movement of the hand wheel 25 is necessary to raise or lower the regulating wheel 7 than was the case when the speed-increasing gearing 26, 34, 33 and 22 was in action. Suitable graduations on the hand wheel thus permit fine adjustment of the distance between the two wheels and in fact an accuracy of adjustment up to one-fourth of one-ten-thousandths of an inch may be achieved. The screw 13, which meshes with the nut (not shown) fixedly carried in the base of the pedestal 10, is always under compression, due to the fact that the weight of the ram 11 and table 12 and of the parts carried thereby is transmitted to the nut through the screw 13; thus, all lost motion is always taken up. It might further be noted that the screw-threaded engagement between the screw 13 and the nut contributes toward effecting a relatively large angular movement of the hand wheel 25 for a given vertical movement of the wheel 7.

The upper end of the pedestal 10 is flanged, as at 14, and resting upon the upper face of the flange 14 is a collar 37 (Figure 8) which is splined to the cylindrical ram 11, by means of a short key 36, so that the collar 37 and ram 11 (the latter with the parts carried thereby) must turn together when swung about a vertical axis. The collar 37 is provided with arcuate slots 38, shown in dotted lines in Figure 9, and passing through these slots are cap screws 39 for clamping the collar 37 to the pedestal 10. When it is desired to achieve an angular relation between the axis of the work-rotating wheel 7 and the axis of the work A, in order to achieve an axial feeding movement of the work, the cap screws 39 are loosened up and the table 12, frame 42 carrying the wheel 7, and the ram 11, are turned about a vertical axis through the desired relatively small angle, all within the limited range permitted by the arcuate slots 38. The collar 37 of course turns with the ram 11 and, as indicated in Figure 1, the collar 37 may be provided with graduations to determine visually the angular relation achieved between the axes of the two wheels. In Figure 1 the graduations indicate a zero angle.

The upper end of the pedestal 10 is slotted and after the desired adjustments of the regulating wheel have been achieved, all as above described in detail, a screw clamp operated by a handle 15 (Figure 9) acts to narrow the slot in the pedestal 10 and thus to clamp the latter tightly about the ram 11, thus locking the latter and the regulating wheel 7 carried thereby securely in adjusted position.

Considering now in detail the mechanism for driving the regulating wheel 7, either very slowly in order to effect control of the rotation of the round work and feeding movement in an axial direction thereof, or at quite high speed in order to effect truing or dressing of the regulating wheel 7, reference may again be made to Figure 8 in which is shown a casing 48 attached to the left-hand portion of the frame 42 by means of screws 51; this casing 48 encompasses the pulley 46 but suitable openings are provided therein to permit the belt 47 to pass around the pulley (see Figure 2). Within this casing 48 is housed and mounted the speed-change mechanism for giving the regulating wheel 7 the preferred alternative speeds above-mentioned.

This speed-change mechanism includes an internal gear 49 (see also Figure 11) non-rotatably and fixedly mounted within the casing 48, as will be clear from Figure 11. A pinion 50 meshes with this internal gear 49 and is rotatably mounted on an eccentric 51 which is preferably formed integrally with the pulley 46. Pinion 50 is greater width in an axial direction than is the internal gear 49 and is of appropriate width so that it may also mean with an internal gear 66 formed in the enlarged cylindrical portion 65 of a sleeve member 62 rotatably supported in the bearing 64 forming the left-hand end closure for the casing 48. The number of teeth of the internal gear 66 is less than, preferably by one or two teeth, the number of teeth 67 on the internal gear 49.

A sleeve 58 extends into the sleeve 62 and is splined to the shaft or spindle 9 by means of the key 57 and keyway 56, so that the sleeve 58, to the outer end of which is secured the hand wheel 59, may be axially moved relative to the spindle 9, though necessarily rotating together. The inner or right-hand end of sleeve 58 is toothed as at 69, and the toothed portions 69 may mesh or interlock with either the teeth 68 formed in the left-hand face of the eccentric portion 52 of the pulley 46 or with the teeth 70 formed on the inner or right-hand end of the sleeve 62, depending

upon whether the sleeve 58, by means of the hand wheel 59, is moved to the right or to the left.

The spindle 9 carries an outwardly spring-pressed ball 60 adapted to coact with suitable recesses on the inner face of the sleeve 58, so as to yieldably hold the sleeve 58 and the clutch-like portions 69 in either the neutral position shown in Figure 8 or in the above-mentioned end positions to the right or to the left.

When the clutch portions 69 are in engagement with the teeth or clutch portions 68, the spindle 9, and hence the work-controlling wheel 7, is directly connected with the pulley 46, and the spindle 9 and wheel 7 are rotated by the pulley many times as fast as when the sleeve 58 is moved to the left and its clutch teeth 69 are caused to interengage with the clutch teeth 70 on the sleeve 62. In the latter position of the parts the spindle 9 and wheel 7 are rotated at a work-regulating speed through the internal gear 66, which is slowly rotated through the medium of the eccentrically mounted pinion 50, which meshes with both the gears 66 and the fixed gear 49.

At the above-mentioned high speed of rotation of the wheel 7, the latter may be dressed or trued. The ratio of the respective work-controlling and wheel-dressing speeds I prefer to be not less than 1 to 20 and not more than 1 to 50, but these ratios may be departed from, depending upon various factors met with in practice.

With the hand wheel 59 and the clutch teeth 69 in the position shown in the drawings, the drive of the wheel 7 is halted since the clutch member 69 is in neutral position, being in engagement with neither the clutch parts 68 nor the clutch parts 70.

A collar 51ª carried within the enlarged portion 65 of the rotatable sleeve 62 engages the left-hand end face of the pinion 50 and holds it in position on the eccentric 52. The parts are appropriately lubricated. For example, an oil passage 53 connects the oil groove 55 with the bearing surface of the pinion 50 and the bearing surface of the eccentric 52, while a suitable oil cup, or the like, 63 supplies oil to the relatively rotatable parts 64, 62 and 58.

While the bearings for supporting the spindles of the two wheels may be of any suitable construction, I find a construction like that shown in Figure 12 desirable. A bearing cap 72 is secured to the frame 42 by cap screws 73 and grips a split sleeve 74 within which is a split bearing bushing 75 rotatably supporting the spindle 9. Along the split in the bushing 75 may be provided a suitable number of tapered plugs 76 controlled by a screw 77 in the cap 72. The tapered plugs 76 may be controlled by the screws 77. By means of nuts 75ª, at the left-hand end of the bearing (see Figure 8) the bushing may be moved endwise.

Considering now the manner in which the work pieces are held in operative relation to the grinding wheel 3 and the work-controlling wheel 7, it is first to be noted, referring to Figures 1 and 5, that the main frame 1 is provided with vertically extending guiding ways 80 along which is vertically slidable a carriage 86 provided with a generally horizontally extending frame-like portion carrying two horizontally spaced work-holding members 109 which extend between the adjacent operative surfaces of the two wheels to form with the latter what may be termed a four-sided grinding throat. These parts will be described more fully hereinafter. A gib 87 (Figure 3) secured to the carriage 86 by screws 88 coacts with the guides 80.

The vertical position of the carriage 86 along the ways 80, and hence the spacing of the work-holding members 109 from the wheels, is determined by a mechanism better illustrated in Figure 5. Turning to Figure 5, the carriage 86 will be seen to have rotatably supported therein a screw 82 which passes through a nut 81 fixedly secured to the frame 1. A suitable bearing 94 supports the upper end of the screw 82, while keyed to the lower end thereof is a sleeve or hub 83 having integrally formed therewith a bevel gear 84, the part 83 being journaled in the bearing portion of a bracket 90 which is secured to the lower portion 85 of the carriage 86 and which rotatably supports also a shaft 89. The shaft 89 carries a bevel gear 92 meshing with the gear 84 and at its outer end has secured thereto a hand wheel 93. By manipulating the hand wheel 93 the screw 82 is rotated and the carriage 86 and the work-holding members 109 raised or lowered.

Extending to the left, as viewed in Figure 1, and to the right, as viewed in Figures 3 and 7, from the carriage 86 and preferably integrally formed therewith, is what may be termed a guide frame formed to provide two spaced guide members 95 and 96 (see Figure 6) each reinforced, to make it more rigid with respect to the carriage 86, by inclined bracing flanges 97. The grinding wheel 3 extends between the guide members 95 and 96, the latter being joined at their outer ends by a cross-piece 120 preferably formed integrally therewith. The under faces and outer side faces of the members 95 and 96 are suitably machined to slidably receive the spaced carriages 98 and 113, one on each side of a line joining the axes of the two wheels (see Figure 1).

Referring to Figure 6, the carriage 95 will be seen to rest against the under faces of the guide members 95 and 96 and is provided with the side portions 99 which have secured thereto, by the screws 102, the inwardly extending members 100 which overlap the lat-

erally projecting portions of the guide members 95 and 96. The carriage 98 is thus slidable lengthwise of the members 95 and 96, and it may be adjustably positioned along the latter by means of a screw 104, operated by the hand wheel 108; the screw 104 is threaded in a nut 107 (Figures 3, 7 and 1) in the carriage 86, and its inner end passes through a boss 103 (Figure 6) on the carriage 98, collars 105 and 106 (Figure 3), one on each side of the boss 103, being fixed to the screw 104 to cause the carriage 98 to move with the screw when the latter moves axially as it is turned with respect to the nut 107.

The carriage 98 carries a work-holding member 109, preferably taking the form of a bar or plate-like member shown more clearly in Figure 13. The member 109 extends underneath and transversely of the spaced guiding members 95 and 96 (see Figure 3) and is secured to the carriage 98 by means of cap screws 110 which pass through suitable recesses 111 (Figure 13) in the ends of the member 109.

As shown in the drawings, one of the longitudinal edge faces of the member 109 is beveled, and as is clear from Figure 1 of the drawings, this inclined end face is presented toward the work A to be contacted by the latter.

As the carriage 98 is adjustably positioned along the guiding members 95 and 96, in response to the actuation of the hand wheel 108, the work-holding member 109 carried thereby is correspondingly adjustably positioned, as will be clear from Figures 1 and 7.

The coacting work-holding member 109, that is, the left-hand member 109, as seen in Figure 1, is secured in a similar manner to the carriage 113, the latter being of substantially similar construction to that of the carriage 98. The carriage 113 extends across the under faces of the guide members 95 and 96 (see Figures 3 and 4) and has side portions 114 (Figure 4) extending upwardly and exteriorly of the members 95 and 96, inwardly directed plate-like members 115, secured to the portions 114 by screws 102, overlapping the lateral projecting portions of the guide members 95 and 96. Thus, the carriage 113 is slidable lengthwise of the members 95 and 96.

The carriage 113 with the work-holding members 109 carried thereby may be adjustably positioned by operating the hand wheel 118 (Figures 1, 3 and 7); the hand wheel 118 actuates a screw 117 which is threaded in a nut 119 carried by or formed in the crosspiece 120 which joins the ends of the guide members 95 and 96. The inner end of the screw 117 passes through a boss 116 (Figures 3 and 7) on the carriage 113, collars 105 and 106, one on either side of the boss 116 and secured to the screw 117, causing the carriage 113 to move with the screw 117 as the latter moves longitudinally during its rotation relative to the nut 119.

The work-holding member 109 carried by the carriage 113 is of similar construction to that hereinabove described in connection with the carriage 98; as is clear from the drawings, Figure 1, for example, it also presents to the work A a surface that will be seen to be inclined.

In Figure 1 of the drawings the work-holding members 109 are shown in substantially the same horizontal plane and both above the center or axis of the work A. I wish to point out, however, that this is a preferred relation of these parts with respect to the work and/or the wheels, but that the position thereof may be varied, if desired. For example, the two members 109 may be positioned in different planes as, for example, one may be offset vertically relative to the other. The end faces of the members 109 and which faces contact with the work preferably are shaped to be tangent to the latter, as well as inclined, as indicated in Figure 1, for example, of the drawings.

Considering now briefly the operation of the apparatus, it is first to be noted that the grinding wheel 3, as above pointed out, is rotated at a suitable grinding speed; the lower wheel 7, which is to control the rotation of the work A and to cause axial feeding movement of the work, is driven at the relatively very slow speed achieved when the hand wheel 59, sleeve 58, and clutch member 69 (see Figure 8) are moved to the left from the position shown in Figure 8. The distance between the two wheels is predetermined by manipulating the hand wheel 25 to raise or lower the wheel 7 to an appropriate position with respect to the grinding wheel 3. The carriage 86 is suitably positioned, by means of the hand wheel 93, in turn to position the work-holding members 109 appropriately with respect to the two wheels, preferably in substantially the relative position shown in Figure 1. The carriages 118 and 113, carried by the horizontal guides 95 and 96 of the carriage 86, are suitably adjusted along the guides 95 and 96, by means of the hand wheels 108 and 118 respectively to space the work-holding members 109, carried by these carriages, appropriately relative to the diameter of the work A to be operated upon. Thus, a four-sided grinding throat, made up by the grinding wheel 3, the work-controlling wheel 7, and the two horizontally spaced work-holding members 109, is preliminarily adjusted to receive the work to be operated upon. Where it is desired to cause the work A to move axially through the grinding throat, the work-controlling wheel 7 is swung about a vertical axis to provide the desired relatively small "feed angle" between the direction of travel of the operative surface of the wheel 7 and the path of travel of the work A, as deter-

mined by the work-holding members 109. All of the above-mentioned adjustments have been described in detail hereinabove, but it might additionally be noted that the work-holding members 109 are so related that they hold the work A with the axis of the latter substantially parallel to the axis of the grinding wheel 3.

The two wheels, rotating at the respective speeds immediately above pointed out, are driven so that they rotate about their axes in the same direction, as viewed in Figure 1, for example. Thus, both wheels may be made to rotate in counter-clockwise direction, the operative surface of the grinding wheel where it contacts with the work A moving toward the right, and the operative surface of the regulating wheel 7, where it contacts with the work A, moving toward the left. During the operation of the apparatus, the grinding of the work A is substantially all done by the upper or grinding wheel 3, but by making the lower wheel, that is the wheel 7, of some hard material, like a relatively hard abrasive, the grip of the lower wheel on the work A insures proper rotation of the work relative to the grinding wheel 3 and, due to the angular relation above described, also insures positive feed, in an axial direction, of the work whether the latter is in contact with the grinding wheel 3 or not. Thus, I insure positive control of the rotation and feed of the work A, by the wheel 7, all while the grinding wheel 3 performs the grinding operation on the work A.

As above pointed out and as is plainly shown in Figure 2 of the drawings, the operative surface of the regulating wheel 7 is of greater width than the adjacent operative surface of the grinding wheel 3; hence the lower wheel projects to either side of the grinding wheel 3, as the apparatus is viewed in Figure 2. The work pieces to be operated upon, assuming that the direction of feed by the regulating wheel 7 is in a direction from the right to the left, as viewed in Figure 2, are placed upon the right-hand projecting end portion of the wheel 7 and between the correspondingly projecting end portions of the work-holding members 109, the weight of the work pieces A thus positioned being borne entirely by the wheel 7. Due to these relations of the parts, the work pieces thus positioned are set into rotation by the wheel 7, any thrust on the work caused by the wheel 7 during this action being taken up by the left-hand work-holding member 109, as viewed in Figure 1; at the same time, due to the angular relation above-described, the wheel 7 causes the work, while it is thus being rotated, to move axially in a direction from the right to the left, as viewed in Figure 2. The weight of the work, being borne substantially entirely by the wheel 7, is effective, in conjunction with the low surface speed of the regulating wheel 7, to effect such an effective contact of the work with the regulating wheel 7 that the latter can readily insure proper rotation of the work prior to the entry of the work into contact with the grinding wheel 3. Thus, the grinding operation to be performed by the grinding wheel 3 commences upon an already properly rotating work piece.

The proper rotation of the work by the regulating wheel 7 continues as the latter feeds the work axially in a direction from the right to the left, as viewed in Figure 2, until the work is moved to the left beyond the grinding wheel 3, whence the grinding operation is finished. The left-hand portions of the work-holding members 109, projecting to the left of the grinding wheel 3, as viewed in Figure 2, however, still act to hold the work upon and in operative contact with the regulating wheel 7 so that the latter can continue the rotation of the work and feed it away from the grinding wheel, whence it may be removed from the supporting wheel 7. Thus, rotation of the work continues therefore as and when the work moves out of operative contact with the grinding wheel, so that marring or grinding of flats on the work is prevented.

With both wheels rotating in the same direction, that is, in counter-clockwise direction, as in Figure 1, the adjacent operative surfaces of the two wheels, and to which adjacent operative surfaces the work A is presented, travel in opposite directions with respect to a point intermediate thereof.

Considering certain further actions that take place in the operation of the apparatus, it might first here be noted that, when a work piece is placed upon the projecting portion of the regulating wheel 7, the weight of the work holds it down on the regulating wheel so that the latter, with its slowly moving surface, gets a grip on the work and starts the latter rotating. If the regulating wheel is tilted about the vertical axis of the column 11 (Figure 8) so that there exists a proper feeding angle between the path of travel of the operative surface of the regulating wheel 7 and the path of travel in an axial direction of the work A (the path of travel of the work being determined by the work-holding members 109), the regulating wheel will also move the rotating work axially into contact with the grinding wheel and continue to rotate and feed the work even after the work passes out of contact with the grinding wheel. Also, if any under-sized work is inserted into the apparatus, the under-sized work will be rotated and fed and there is no danger of it being marred or touched by the grinding wheel, since the work is effectively urged, by its weight, away from the grinding wheel and against the regulating wheel.

Any thrust on the work, caused by the

movement of the operative surface of the regulating wheel 7 in a direction toward the left, as viewed in Figure 1, is taken up by the left-hand work-holding member 109; this particular work-holding member 109 thus insures that the work A has its axis properly held with respect to the axis of the regulating wheel so that the feeding action of the wheel 7, while the work A is out of contact with the grinding wheel 3, may be dependably carried on.

While the grinding wheel performs the grinding operation, there takes place a coaction of one of the work-holding or supporting members 109 with the regulating wheel; if the wheels are rotating in counter-clockwise direction, the thrust of the grinding wheel 3 on the work A, all as viewed in Figure 1, is taken up by the right-hand member 109. This member, however, will be seen to have, as above noted, a surface, with which the work A contacts, which makes an obtuse angle with a plane tangent to the grinding wheel 3 at the line of contact of the grinding wheel 3 with the work A. This inclined surface of the right-hand work-holding member 109 is the surface by which the thrust of the grinding wheel 3 on the work A is taken up and has such an inclination that a component of the grinding wheel thrust is exerted in a direction to dependably urge the work toward or against the regulating wheel 7 and thus further insure effective contact between the surface of the regulating wheel and the work so that the former dependably controls the rotation and feed of the latter. Under certain conditions, also, this inclined surface of that work-holding member which takes up the thrust of the grinding wheel on the work is of great aid in bringing about speedily a true rounding-up of the work operated upon.

A water pipe 102 (see Figures 3 and 1) is connected to the cross-piece 120 (see also Figure 4), the latter being provided with suitable passages 123 for guiding water to the point of contact between the grinding wheel and the work as the grinding wheel rotates in counter-clockwise direction, as viewed in Figure 1. A plate 124 (see Figure 7) is positioned to catch and guide away water that is thrown off of the grinding wheel 3, the latter, in Figure 7, rotating in clockwise direction, the view of Figure 7 being from the rear of the apparatus as the latter is seen in Figure 1.

Because of the angular relation of the lower wheel 7 to the axis of the work when the wheel 7 is positioned to cause axial feeding movement of the work the surface of the regulating wheel 7 which supports the work and which for accuracy of results, should support the work perfectly throughout its length, is necessarily a curve and this curve is substantially hyperbolic. The regulating wheel 7 is trued to give it the desired curved surface so that it will present a straight line of contact to the work when it is adjusted to feed the work axially.

Considering now the apparatus for truing the wheels, reference may now be had to Figures 1, 3 and 7. The underside of the carriage 113 is provided with spaced lugs 130 (see Figure 2) and these lugs support a shaft or rod 131 to the outer ends of which are secured the brackets 132 and 133 (see Figures 2 and 3). Brackets 132 and 133 extend generally in a vertical plane and are preferably shaped, in side elevation, as is better shown in Figures 1 and 7, from which it will be seen that the brackets are provided with arcuate slots 134, the center of curvature of which is coincident with the axis of the shaft or rod 131.

Screws 135 are threaded into the sides of the carriage 113 and pass through the arcuate slots 134 so that the arms or brackets 132 and 133 may be locked in whatever position they may be swung within the range permitted by the arcuate slots. During the normal operation of the apparatus, the brackets which, being attached to the rod 131, swing as a unit with the latter, are moved and held in their uppermost position, as is better shown in Figure 1.

The ends of the arms or brackets 132 and 133 remote from the rod 131 are provided with suitable openings; thus, a hole or opening 139 in the outer end of the bracket 132 is adapted to receive a bushing 138 while a similar hole or opening in the bracket or arm 133 receives the reduced end 143 of a sleeve 142, the latter being better shown in Figures 2 and 14. Set screws 144 (Figure 3) serve to lock the bushing 138 and the sleeve 142 to their respective brackets. The central bores of the bushing 138 and of the sleeve 142 are alined and are adapted to slidably guide a round rod 140 (see Figure 3). The rod 140 carries a suitable cutting tool, such as a diamond 146, adapted, when drawn across the face of either of the two wheels, to turn the latter down, as the rod 140 is moved longitudinally with respect to itself, a knob 147 being provided to permit ease of manual sliding movement of the rod 140.

The sleeve 142, better shown in Figure 14 on an enlarged scale, is provided with a straight slot 148 (see Figure 3) extending through its wall and substantially diametrically opposite this slot 148 there is formed in the sleeve a helical slot 150 (Figure 14). A screw 145 threaded into the rod 140 is adapted to coact with either of these two slots.

When it is desired to dress or true the grinding wheel 3, the brackets 132 and 133 are swung downwardly from the position shown in Figure 1, the sleeve 142 is secured in place in the bracket 133 with the straight

slot 148 uppermost, as is shown in Figure 3, and the bushing 138 secured in place in the bracket 132. The rod 140 is then slid through the bushing 138 and into the sleeve 142, and the screw 145 passed through the slot 148 and threaded into a suitable opening in the rod 140. The threaded opening in the rod 140 and the diamond 146 are so positioned or located that, when the screw 145 is assembled as above-described, the diamond 146 will project upwardly from the rod 140, all as shown in Figure 3. The brackets 132 and 133 are then locked in position by means of the locking screws 135, it being noted that the rod 140 is thus positioned and held in parallelism with the axis of the grinding wheel 3.

The carriage 86 (see Figures 1 and 7) is then elevated by manipulating the hand wheel 93 so as to raise the rod 140, with the diamond 146 thereon, to such a height that the rod 140 may be manually moved lengthwise of itself and the diamond 146 drawn across the face of the grinding wheel 3 to turn the latter down and dress it to its proper shape. During this sliding movement of the rod 140 the screw 145 (see Figure 3) is guided by the straight slot 148 in the sleeve 142 so that the cutting point of the diamond 146 moves along a straight line. During this operation the grinding wheel 3 is, of course, rotated at a grinding speed.

If the regulating wheel 7 is set so that it exerts no feeding component upon the work A, and it is desired to true the wheel 7 to suit this condition, the set screw 144 (Figure 3) is loosened up and the sleeve 142 rotated through 180° and again locked in position, the diamond 146 being now positioned on the underside of the rod 140 and in position to operate upon the wheel 7. The carriage 146 is then lowered by manipulating the hand wheel 93 (Figure 1) so as to bring the diamond 146 to a suitable position for engaging and cutting the wheel 7 to the desired depth. The wheel 7 is driven at high speed during this truing operation, the speed-change mechanism shown in Figure 8 and hereinabove described in detail being adjusted or set to give the high truing speed. The diamond 146 is then drawn across the wheel 7 in a manner that will be clear from what has been set forth above in regard to truing the grinding wheel 3.

If, however, the wheel 7 is to be set at an angle to give the desired or appropriate rate of axial feeding movement to the work being operated upon, the sleeve 142, instead of being rotated through 180°, as above described, is left in the position shown in Figure 3; the wheel 7 is left in the position for no feeding action and the screw 145 removed from the rod 140. The rod 140 is then rotated through 180° from the position shown in Figure 3, so that the diamond 146 now projects downwardly, and the threaded opening that receives the screw 145 also exposed downwardly. The screw 145 is then replaced, but this time through the helical slot 150 (see Figure 14). As the diamond 146 is now moved across the face of the wheel 7, the latter running, of course, at a high or truing speed, the helical slot 150 causes a relatively slight swinging of the rod 140 about its axis in order thereby to vary or change the depth of cut being taken by the diamond 146. The helical slot 150 is given a pitch proportional to the angle of feed which it is desired to give the wheel 7 with respect to the axis of the work and through which angle the table 12 and the wheel 7 are to be swung in order to achieve a corresponding rate of feed. The wheel 7 is thus given the desired curvature so that, when it is subsequently swung through the desired feed angle, it will present to the work a straight line of contact therewith.

During these truing operations the rod 140 may be moved back and forth longitudinally as often as is desired to give the wheels the desired smoothness of exposed surface. Of course, after the truing of the regulating wheel 7 has been accomplished, the speed-change mechanism is adjusted to a position such that the wheel 7 will be driven at the requisite low speed to effect control of rotation and control of feed of the work.

In order to facilitate adjusting of the wheels to receive therebetween a predetermined diameter of work, a graduated rod 153 (see Figures 1, 3 and 7) is carried by one of the horizontally extending guide members 95, being preferably mounted in a boss 154 and being vertically adjustable. A set screw 155 serves to lock the graduated rod 153 in any desired position.

The rod 153 extends downwardly through the guide member 95 and at its lower end is provided with a finger 156 extending transversely thereof and which may be swung inwardly to engage the face of the grinding wheel 3. The graduations carried by the rod 153 may then be read and, assuming that the apparatus is to operate upon work of half inch diameter, the finger 156 and rod 153 may be moved downwardly half an inch, gauged by the graduations, and locked in position. The regulating wheel 7 may then be raised by the mechanism hereinabove described in connection with Figures 8, 9 and 10 so as to bring the surface of the regulating wheel 7 into contact with the finger 156. The latter with its carrying rod 153 may then be moved out of the way, test pieces may be put through the apparatus and final adjustments to achieve the intended diameter made by the mechanisms hereinabove described in detail.

Preferably the guide blades or work-holding members 109 are positioned so that their

work-contacting faces will hold the work with the axis of the latter parallel to the axis of the grinding wheel where the latter is operative by its peripheral or rim face.

It will thus be seen that there has been provided in this invention a grinding apparatus in which the several objects and advantages hereinbefore noted, as well as many others, are successfully achieved. It will be seen that the apparatus is of thoroughly dependable construction and action and capable of high degree of accuracy and efficiency of grinding and that it is well adapted to meet the varying conditions of hard practical use.

As many possible embodiments may be made of the above invention and as many changes might be made in the embodiment above set forth, it is to be understood that all matter hereinbefore set forth or shown in the accompanying drawings, is to be interpreted as illustrative and not in a limiting sense.

I claim:—

1. A centerless grinding machine comprising a horizontal arbor, a grinding wheel thereon, a table substantially below said grinding wheel and rotatable about a substantially vertical axis which passes substantially through the center of the grinding wheel, an arbor mounted on the table and adapted to swing in a horizontal plane when said table is swung about said vertical axis, a work-supporting and regulating wheel on the lower arbor, means to rotate the regulating wheel slowly and the grinding wheel rapidly to respectively rotate and grind the work, and means to hold work between and in contact with the wheels.

2. In a grinding machine, a grinding wheel; a table below the grinding wheel and pivoted to swing about a substantially vertical axis; a spindle mounted on the table and adapted to swing in a substantially horizontal plane upon said table being swung about its pivot; a work-rotating and supporting wheel on said spindle; and means to guide work between the wheels comprising a guide frame, carriages mounted on the guide frame, guide plates mounted in the carriages, and means to adjust the carriages independently of each other.

3. In a grinding machine, a grinding wheel; a table below the grinding wheel and pivoted to swing about a substantially vertical axis; an arbor mounted on the table and adapted to swing in a substantially horizontal plane upon said table being swung about its pivot; a work-rotating and supporting wheel on said arbor; and means to guide work between the wheels comprising a guide frame, means to raise and lower the guide frame, guide plates to engage the work, and independently operable screws to position the guide plates.

4. In a centerless grinding machine, a grinding wheel; a table underneath said grinding wheel and pivoted to swing about a substantially vertical axis; a spindle rotatably mounted on the table and adapted to swing in a substantially horizontal plane upon said table being swung about said axis; a work-regulating and supporting wheel on said spindle; means to rotate the regulating wheel slowly and the grinding wheel rapidly to respectively rotate and grind the work; means to guide work between the wheels; means to raise and lower the work-guiding means; and means to raise and lower said table and with it said supporting wheel.

5. In a grinding machine, a grinding wheel; a table below the grinding wheel and pivoted to swing about a substantially vertical axis; bearings on the table; a substantially horizontal spindle in said bearings; a peripheral supporting wheel mounted on said spindle and having a greater width than said grinding wheel to support the work after it leaves the upper wheel, means for rotating the said wheels at respective speeds and with their adjacent operative surfaces traveling in such directions as to effect simultaneous grinding and rotation of the work, and a pair of spaced members extending lengthwise between said wheels for receiving therebetween work of round section and for holding it in operative contact with said wheels.

6. In a grinding machine, a horizontal arbor, a peripheral grinding wheel thereon, a table below the grinding wheel and pivoted to swing about a substantially vertical axis, bearings on the table and a substantially horizontal spindle in said bearings, a peripheral work-supporting wheel of greater width than the grinding wheel and mounted on said spindle, a pair of spaced plates to hold round work between the wheels, and means to rotate the arbors in the same direction, the surface speed of the peripheral face of the supporting wheel being so low that said supporting wheel controls the rotation of the work.

7. In a grinding machine, a frame, an arbor rotatably mounted therein, a grinding wheel on the arbor, an arbor mounted below said grinding wheel, a supporting wheel on the lower arbor having a work-engaging face of greater width than that of the grinding wheel, a pair of spaced adjustable guide plates between the wheels adapted to engage cylindrical work supported by the lower wheel, and means to rotate the supporting wheel slowly and the upper wheel rapidly to respectively rotate the work positively and grind the same.

8. In a grinding machine, a frame, a horizontal arbor rotatably mounted therein, a grinding wheel on the arbor, a frame rotatable on a vertical axis below and in the vertical plane of the upper arbor, a horizontal arbor mounted in the rotatable frame, a supporting wheel on the lower arbor of greater length than the upper wheel, a pair of adjust-

able guide plates between the wheels adapted to engage cylindrical work supported by the lower wheel, the opposed work-contacting edge faces of the plates making an angle with each other and being tangent to the cylindrical work.

9. In a grinding machine, a pair of arbors, one directly above the other, a wheel on each arbor, the upper wheel on the upper arbor being a grinding wheel, a pair of spaced parallel work-holding members to guide cylindrical work between the two wheels and parallel to the upper arbor, means to rotate the upper wheel rapidly to grind the work and the other slowly to control the rotation of the work, and means to move said members transversely to the vertical plane of the upper arbor, the opposed edges of the work-holding members being tangent to the work.

10. In a grinding machine, a frame, a horizontal arbor rotatably mounted therein, a grinding wheel on the arbor, a table rotatable on a vertical axis below and in a plane passing substantially vertically through the upper arbor, a horizontal arbor mounted in the rotatable table, a wheel made of abrasive material on the lower arbor of greater width than the upper wheel, a high and low speed changing device also mounted on the lower arbor to drive the same for the purpose herein set forth, and a pair of spaced guide plates between the two wheels adapted to hold round work between the wheels.

11. In a grinding machine, a horizontal arbor, a peripheral grinding wheel thereon, a table below the grinding wheel and pivoted to turn about a vertical axis, bearings mounted on the table and a horizontal arbor in said bearings below the grinding wheel, a peripheral abrasive wheel of greater width than the grinding wheel and mounted on the lower arbor, a pair of spaced members to guide cylindrical work between the wheels, and means to rotate the arbors in the same direction and at substantially the same speed for truing or at such different speeds that only the upper wheel grinds and the lower wheel controls the rotation of the work.

12. In a grinding machine, a horizontal arbor, a grinding wheel thereon, a table below the grinding wheel and pivoted to turn about a vertical axis, an arbor mounted on the table below the first-mentioned arbor and adapted to swing in a substantially horizontal plane upon turning of the table, a work-supporting and regulating wheel on the lower arbor, adjustable means to guide round work between the wheels, and means to raise and lower said table and with it the lower wheel.

13. In a grinding machine, a horizontal arbor, a grinding wheel thereon, a table below the grinding wheel and pivoted to turn about a vertical axis, an arbor mounted on the table below the first-mentioned arbor and adapted to swing in a substantially horizontal plane upon turning of the table, a work-supporting and regulating wheel on the lower arbor and having a wider face than the upper wheel, and spaced work-holding members mounted between the wheels to guide the work in a straight line past the upper wheel and also when the work is out of contact with the grinding wheel.

14. In a grinding machine, a horizontal arbor, a grinding wheel thereon, a rotatable table with its center in the vertical plane of the arbor, bearings mounted on the table and a horizontal arbor in said bearings, a wheel of abrasive material of smaller diameter but of greater width than the first, means also mounted on the lower arbor for starting and stopping the lower wheel, and guides mounted parallel to the upper wheel and between the two wheels adapted to be moved toward and from each other independently so that they may be positioned to guide the work so its central line is either in line, or to one side of the vertical plane of the upper arbor.

15. A centerless grinding machine comprising a base. a peripheral grinding wheel mounted to rotate about a horizontal axis, a peripheral work-regulating wheel mounted to rotate about a horizontal axis and located below the grinding wheel, means to rotate the grinding wheel rapidly and the regulating wheel slowly to respectively grind and rotate the work, and means to hold work between and in contact with the peripheries of the wheels in such a location that a line connecting the work center and a wheel center makes an angle with a line connecting the wheel centers so that the work will be ground at one side of the throat between the wheels.

16. A centerless grinding machine comprising a base, two peripherally opposed abrasive wheels mounted thereon to rotate about horizontal axes, one above the other, spaced work-holding members mounted on the base and arranged to contact with cylindrical work along lines parallel with the axis of one of said wheels, and means to adjust said members vertically and horizontally to grind all sizes of work, said parts being so constructed and arranged that said members may contact with the work in a plane perpendicular to the plane connecting the wheel axes and so that the work may be ground on a line at one side of a plane connecting the wheel axes.

17. A centerless grinding machine comprising a base, a grinding wheel mounted thereon for rotation, a work-supporting and regulating wheel opposed to the grinding wheel, means to rotate the grinding wheel at a rapid rate and the regulating wheel at a work-regulating rate, two adjustable spaced work-holding members mounted to hold round work between and in contact with the operative surfaces

of the wheels, means to move the said members toward and from each other, and means to move said members as a unit toward and from one of the wheels and substantially at right angles to the first-mentioned movement.

18. A centerless grinding machine comprising a base, a grinding wheel mounted thereon for rotation, a work-regulating wheel below the grinding wheel, means to rotate the grinding wheel at a rapid rate and the regulating wheel slowly, two adjustable spaced work-holding members mounted to hold round work between and in contact with the opposed operative surfaces of the wheels, a vertically movable support for said members, a manually operable screw to move the support, and separately operable screw-threaded means to move said members horizontally for any position of the support so as to adjust the members finely relative to work of various sizes.

19. A centerless grinding machine comprising a base, a grinding wheel and a work-supporting and regulating wheel mounted thereon to rotate about horizontal axes in peripheral opposition, adjustable means supporting the regulating wheel which permits it to be skewed relative to the grinding wheel so as to feed the work axially, means to hold work between and in contact with the wheel peripheries, means to rotate the grinding wheel rapidly and a multi-speed clutch mechanism including a manually operable control device located on the machine which is operable for any position of the regulating wheel to rotate it rapidly for truing or at a slow speed for work regulation.

20. A centerless grinding machine comprising a grinding wheel and a regulating wheel mounted to rotate about horizontal axes, a support for the regulating wheel movable toward and from the grinding wheel to accommodate different sizes of work, and rotatable about a line passing through the wheel centers so that the regulating wheel may be skewed relative to the grinding wheel so as to cause axial feeding movement of the work, means to hold work in peripheral contact with the two wheels on the machine, means to rotate the grinding wheel rapidly, and separate clutch-controlled power connections to rotate the regulating wheel slowly during its feeding action on the work while the grinding operation is performed by the grinding wheel or rapidly for truing the regulating wheel.

21. A centerless grinding machine comprising a rapidly rotatable grinding wheel, a slowly rotatable regulating wheel below the grinding wheel, said wheels being relatively movable towards and from each other, a work holding member therebetween, precision mechanism to adjust the work holding member vertically, and precision mechanism to adjust it horizontally relative to the wheels, said member having its operative face lying at an obtuse angle to a tangential plane passing through the line of contact of the grinding wheel and work whereby the thrust of the grinding wheel and gravity cooperate to cause the work to maintain contact with the regulating wheel.

22. A centerless grinding machine comprising a rapidly rotatable grinding wheel, a slowly rotatable regulating wheel, two spaced work holding members located between the wheels, means to move one of the wheels towards and from the other, means to move said members towards and from each other, and means to move the members towards and from one of the wheels in a direction at right angles to the other direction of movement, that member which receives the grinding wheel thrust having a beveled face which lies at an obtuse angle to a tangential plane passing through the line of contact of the grinding wheel and work, whereby the work tends to maintain contact with the regulating wheel.

23. In grinding apparatus, in combination, a grinding wheel adapted to be rotated at a relatively high speed, a regulating wheel adapted to be rotated at a relatively low speed, said wheels being adapted to present adjacent operative surfaces traveling in opposite directions, means for holding work of round section in operative relation to said wheels, means mounting said regulating wheel to permit the relation of its axis and hence to permit the inclination of the path of travel of its operative surface to be changed relative to the path of travel of work along said work-holding means, and means for driving said regulating wheel, said driving means including speed-change mechanism operative throughout the range of change in relation of said regulating wheel.

24. In grinding apparatus, in combination, a grinding wheel adapted to be rotated at a relatively high speed, a regulating wheel adapted to be rotated at a relatively low speed, said wheels being adapted to present adjacent operative surfaces traveling in opposite directions, means for holding work of round section in operative relation to said wheels, means mounting said regulating wheel to permit the relation of its axis and hence to permit the inclination of the path of travel of its operative surface to be changed relative to the path of travel of work along said work-holding means, and speed-change mechanism for driving the regulating wheel and supported to be movable with the regulating wheel and throughout the range of change in position of the axis of said regulating wheel.

25. In grinding apparatus, in combination, a grinding wheel adapted to be rotated at a relatively high speed, a regulating wheel adapted to be rotated at a relatively low

speed, said wheels being adapted to present adjacent operative surfaces traveling in opposite directions, means for holding work of round section in operative relation to said wheels, a shaft carrying said regulating wheel, bearing means for rotatably supporting said regulating wheel shaft, means mounting said bearing means to permit the regulating wheel to be moved toward or away from the grinding wheel and to permit change of the angular inclination between the path of travel of the operative surface of the regulating wheel and the path of travel of the work along said work-holding means, and means including a speed-change mechanism operative throughout the range of change in relation of the regulating wheel shaft for driving the latter.

26. In grinding apparatus, in combination, a grinding wheel adapted to be rotated at a relatively high speed, a regulating wheel adapted to be rotated at a relatively low speed, said wheels being adapted to present adjacent operative surfaces traveling in opposite directions, means for holding work of round section in operative relation to said wheels, a shaft carrying said regulating wheel, bearing means for rotatably supporting said regulating wheel shaft, means mounting said bearing means to permit the regulating wheel to be moved toward or away from the grinding wheel and to permit change of the angular inclination between the path of travel of the operative surface of the regulating wheel and the path of travel of the work along said work-holding means, and means for driving said regulating wheel shaft, said driving means including a speed-change mechanism movable with said regulating wheel in a direction toward and away from the grinding wheel.

27. In grinding apparatus, in combination, a grinding wheel adapted to be rotated at a relatively high speed, a regulating wheel adapted to be rotated at a relatively low speed, said wheels being adapted to present adjacent operative surfaces traveling in opposite directions, means for holding work of round section in operative relation to said wheels, means mounting said regulating wheel to permit its adjustment toward or away from the grinding wheel, and means for driving said regulating wheel including a speed-change mechanism movable with said regulating wheel and thus operative throughout the range of movement of the latter.

28. In grinding apparatus, in combination, a pair of opposed abrasive wheels, means for holding work of round section therebetween, and means for driving said two wheels at speeds and in directions to effect simultaneous grinding and rotation of the work therebetween, said driving means including a plurality of members coaxially mounted with one of said wheels and each driven at a different speed, and means for selectively placing one of said members in driving connection with said one wheel.

29. In grinding apparatus, in combination, a pair of opposed abrasive wheels, means for holding work of round section therebetween, means for driving said two wheels at speeds and in directions to effect simultaneous rotation and grinding of the work therebetween, and means for moving one of said wheels to change its relation to the other wheel, said driving means including speed-change mechanism movable with said movable wheel.

30. In grinding apparatus, in combination, a grinding wheel adapted to be rotated at a relatively high speed, a regulating wheel adapted to be rotated at a relatively low speed, said wheels being adapted to present adjacent operative surfaces traveling in opposite directions, means for holding work of round section in operative relation to said wheels, and means for moving one of said wheels to change its relation to the other wheel, said means including a slide upon which said one wheel is mounted, a control member, mechanism interposed between said control member and said slide adapted to move said slide either relatively rapidly or relatively slowly, and selectively controlled means for causing said mechanism to operate at will either rapidly or slowly.

31. In grinding apparatus, in combination, a grinding wheel adapted to be rotated at a relatively high speed, a regulating wheel adapted to be rotated at a relatively low speed, said wheels being adapted to present adjacent operative surfaces traveling in opposite directions, means for holding work of round sections in operative relation to said wheels, and means for moving one of said wheels to change its relation to the other wheel, said means including a slide upon which said one wheel is mounted, a rotatable member, and selectively controlled speed-change mechanism interposed between said rotatable member and said slide.

32. In grinding apparatus, in combination, a main frame having rotatably supported at an upper portion thereof a grinding wheel and provided with means for rotatably supporting a regulating wheel in a position substantially underneath said grinding wheel, means for driving said grinding wheel at a grinding speed and for driving said regulating wheel at a speed and in a direction to control the rotation of work of round section interposed between said wheels, means for moving one of said wheels in a direction toward or away from the other, and means for holding work in operative relation to said two wheels, said last-mentioned means including a substantially vertically movable carriage, a carriage supported by said first-mentioned carriage and movable in a substantially horizontal direction, and a work-

holding member carried by said second-mentioned carriage.

33. In grinding apparatus, in combination, a main frame having rotatably supported at an upper portion thereof a grinding wheel and provided with means for rotatably supporting a regulating wheel in a position substantially underneath said grinding wheel, means for driving said grinding wheel at a grinding speed and for driving said regulating wheel at a speed and in a direction to control the rotation of work of round section interposed between said wheels, means for moving one of said wheels in a direction toward or away from the other, and means for holding work in operative relation to said two wheels, said last-mentioned means including a carriage movable in a substantially vertical direction and provided with guiding ways extending substantially horizontally, a pair of slides mounted in said guiding ways, and a work-holding member carried by each of said slides.

34. In grinding apparatus, in combination, a main frame having rotatably supported at an upper portion thereof a grinding wheel and provided with means for rotatably supporting a regulating wheel in a position substantially underneath said grinding wheel, means for driving said grinding wheel at a grinding speed and for driving said regulating wheel at a speed and in a direction to control the rotation of work of round section interposed between said wheels, means for moving one of said wheels in a direction toward or away from the other, and means for holding work in operative relation to said two wheels, said last-mentioned means including an auxiliary frame provided with substantially horizontally extending guiding ways, a pair of spaced slides mounted in said guiding ways and adjustable toward or away from one another, and a work-holding member carried by each of said slides.

35. In grinding apparatus, in combination, a grinding wheel, an opposed regulating wheel, means for driving said grinding wheel at a grinding speed and for driving said regulating wheel at a slow speed to control the rotation of work of round section interposed therebetween, and means for holding work of round section between said wheels, said last-mentioned means including a frame-like member provided with guiding ways extending in a direction substantially laterally of the grinding throat between said wheels, a pair of slides mounted in said guiding ways and each supporting a work-holding member which extends between the adjacent operative surfaces of said wheels, and means for controlling the position of said slides along said guiding ways.

36. In grinding apparatus, in combination, a grinding wheel rotatable at a relatively high speed, a work-rotating wheel rotatable at a relatively low speed and positioned underneath the grinding wheel, said wheels presenting adjacent operative surfaces traveling in opposite directions, a member extending betweeen said wheels for holding a work-piece in operative relation to the latter and adapted to take up the thrust of the grinding wheel upon the work, said member having a surface with which the work contacts making an obtuse angle to a plane tangential to the grinding wheel at the line of contact of the latter with the work, and a member spaced from said work-holding member and adapted to take up the thrust of the regulating wheel on the work.

37. A centerless grinding machine comprising a rapidly rotatable grinding wheel, a slowly rotatable regulating wheel for controlling the rotation of work of round section, a member for holding work of round section between the wheels having a face arranged to receive the grinding wheel thrust on the work and adapted to contact with the side of the work adjacent to the grinding wheel and remote from the regulating wheel and adapted to cause the work to maintain contact with the regulating wheel, and a second member between the wheels having a face arranged to contact with the substantially opposite side of the work and hold it in position against any thrust of the regulating wheel.

38. A centerless grinding machine comprising a rapidly rotatable grinding wheel, a slowly rotatable work-regulating wheel for controlling the rotation of work of round section, said wheels being peripherally opposed thereto and rotating in the same peripheral direction, means to adjust the distance between said wheels, and two adjustably spaced members arranged on opposite sides of the work to hold it in operative relation with the wheels, that member, which receives the thrust of the grinding wheel on the work, having its operative face lying at an obtuse angle to a tangential plane passing through the line of contact of the grinding wheel and the work, and the other member having a face arranged to receive any thrust of the regulating wheel.

39. A centerless grinding machine comprising a grinding wheel, a regulating wheel mounted in opposition to the grinding wheel, means to hold and guide work of round section between and in contact with said wheels, and means to rotate the regulating wheel slowly and the grinding wheel rapidly to respectively rotate and grind the work, said regulating wheel projecting laterally beyond the side of the grinding wheel so that the work may contact with and be rotated by the regulating wheel while out of contact with the grinding wheel.

40. A centerless grinding machine comprising a grinding wheel, a regulating wheel mounted below and in opposition to the grinding wheel, means to hold and guide work

of round sections between and in contact with the two wheels, and means to rotate the regulating wheel slowly and the grinding wheel rapidly to respectively rotate and grind the work, said lower wheel projecting beyond the grinding face of the upper wheel and the parts being so arranged that the work may be supported and rotated by the lower wheel while out of contact with the grinding wheel.

41. A centerless grinding machine comprising a peripherally operative grinding wheel rotatable about a substantially horizontal axis, a regulating wheel mounted below and in peripheral opposition to the grinding wheel, means to hold cylindrical work on the regulating wheel and in contact with and axially substantially parallel to the axis of the grinding wheel, means to rotate the regulating wheel slowly and and grinding wheel rapidly to respectively rotate and grind the work, and means to guide the work into and out of contact with the wheels, said lower wheel projecting laterally beyond the side of the grinding wheel so that the work may be positively rotated thereby while out of contact with the grinding wheel.

42. A centerless grinding machine comprising a pair of arbors, one above the other, a grinding wheel on one and a regulating wheel on the other, a pair of guides between the wheels arranged to position work therebetween in contact with the wheels and with its axis substantially parallel with the axis of the grinding wheel, means for adjusting the positions of the guides to accommodate different sizes of work, and means to rotate the regulating wheel slowly and the grinding wheel rapidly to respectively rotate and grind the work.

43. A centerless grinding machine comprising a grinding wheel, a work-regulating wheel mounted in peripheral opposition to and below the grinding wheel, means to rotate the grinding wheel rapidly to grind work of round section interposed between the two wheels, means to rotate the regulating wheel to control the rotation of the work, and means to hold work between and in contact with the peripheries of said wheels.

44. A centerless grinding machine comprising a grinding wheel, a work-regulating wheel mounted in peripheral opposition to and below the grinding wheel, means to rotate the grinding wheel rapidly and the regulating wheel slowly to respectively grind and rotate work of round section interposed therebetween, means for holding work between the wheels, and a support for the work-regulating wheel constructed and arranged to permit said wheel to be angularly positioned relative to the work axis so that it feeds cylindrical work axially past the grinding wheel.

45. A centerless grinding machine comprising a peripherally operative grinding wheel rotatable about a horizontal axis, a work-regulating wheel mounted in peripheral opposition to and below the grinding wheel, means to rotate the grinding wheel rapidly and the regulating wheel slowly to respectively grind and rotate work of round section interposed therebetween, and a guide arranged to hold work in contact with the wheels and axially substantially parallel with the axis of the grinding wheel.

46. A centerless grinding machine comprising two peripherally operative abrasive wheels mounted in peripheral opposition, one above the other, driving mechanism to rotate said wheels in the same direction about their axes, one wheel rapidly to grind the work and the other slowly to control the rotation of the work, means to hold work of round section between and in contact with the wheels, and means to adjust the distance between said wheels for accommodating different sizes of work.

47. A centerless grinding machine comprising two abrasive wheels mounted one above the other with their operative faces in opposition, means to rotate the upper wheel rapidly to grind work of round section and the lower wheel slowly to control the rotation of the work, a guide to hold work of round section between and in contact with the wheels and arranged so that the work may be supported wholly on the lower wheel, and means to adjust the axis of the lower wheel at an angle relative to the axis of the work so as to feed the work axially during the grinding operation thereon by the grinding wheel.

48. A centerless grinding machine comprising a grinding wheel and a regulating wheel mounted so that the grinding wheel is above the regulating wheel, means to rotate the upper wheel rapidly to grind the work and the lower wheel slowly to control the rotation of the work, a member to hold cylindrical work between and in contact with the wheels, said parts being so arranged that the work is supported wholly on the lower wheel, means to adjust the axis of the lower wheel at an angle relative to the axis of the work so as to feed the work axially during the grinding operation thereon by the grinding wheel, and means for adjusting the distance between the two wheels.

49. A centerless grinding machine comprising a grinding wheel and a feed wheel mounted so that the grinding wheel is above the other and with their operative faces in opposition, means to rotate the grinding wheel rapidly to grind work of round section and the feed wheel slowly to grip the work, a member to hold work on the lower wheel and in contact with the grinding wheel, means to adjust the axis of the feed wheel at an angle relative to the axis of the work so as to feed the work axially during the grinding operation thereon by the grinding wheel,

and precision mechanism to move the feed wheel toward and from the grinding wheel.

50. A centerless grinding machine comprising a base, a grinding wheel mounted in fixed bearings thereon, a slide mounted on the base beneath and for movement toward and from the grinding wheel, a work-regulating wheel rotatably mounted on said slide and arranged to be swiveled about a vertical axis, means to rotate the grinding wheel rapidly to grind work of round section and the regulating wheel slowly to determine the rate of rotation of the work, and means to maintain work on the lower wheel and in contact with the periphery of the grinding wheel, which permits the work to be supported wholly by the regulating wheel and ground only by the upper wheel.

51. A centerless grinding machine comprising a base, a peripherally operative grinding wheel, bearings fixed on the base to support the grinding wheel with its axis substantially in a horizontal plane, a support mounted on the base beneath the grinding wheel for vertical and rotative movement, a regulating wheel mounted on said support in peripheral opposition to the grinding wheel and arranged to be skewed relative to the grinding wheel by movement of its support, driving mechanism to rotate the grinding wheel rapidly and the regulating wheel slowly, and means to hold work on the regulating wheel and in contact with the grinding wheel periphery, whereby the work may be rotated and axially fed by the regulating wheel and ground by the grinding wheel.

52. A centerless grinding machine comprising a base, a peripherally operative grinding wheel mounted in horizontal bearings thereon, a regulating wheel which is wider than the grinding wheel mounted beneath and in peripheral opposition to the grinding wheel, a member mounted on the base to hold work of round section axially substantially parallel with the axis of the grinding wheel and adapted to permit the work to be supported on the regulating wheel, and means to rotate the grinding wheel rapidly and the regulating wheel slowly, said parts being so constructed and arranged that the work will be rotated and fed axially by the regulating wheel before and after contacting with the grinding wheel.

53. A centerless grinding machine comprising a base, a grinding wheel rotatably mounted thereon, a support rotatable about an axis extending substantially normal to the operative face of the grinding wheel and slidably mounted for movement toward and from the grinding wheel, a work-regulating wheel rotatably mounted on said support in opposition to and adapted to be tilted relative to the grinding wheel, means to rotate the grinding wheel rapidly and the regulating wheel slowly, and a guide to position work in contact with the peripheries of said wheels, said parts being so constructed and arranged that the work bears against the regulating wheel under the influence of gravity and it will be ground by the grinding wheel while being rotated and fed axially by the regulating wheel.

54. A centerless grinding machine comprising a base, a grinding wheel and a work-regulating wheel mounted thereon with the grinding wheel above the regulating wheel, means to rotate the grinding wheel rapidly and the regulating wheel slowly, means to hold work of round section between the wheels and in contact therewith so that the work is supported on the lower wheel, and means for adjusting the work-holding means vertically and horizontally.

55. A centerless grinding machine comprising two wheels having opposed abrasive faces, means to rotate one wheel rapidly to grind work of round section and the other slowly to regulate the rotation of the same, means rotatably supporting said wheels with the regulating wheel underneath the grinding wheel, means to regulate the distance between the wheels to permit grinding work of different sizes, and an adjustably positioned member to hold the work between and in contact with the abrasive faces, said parts being so constructed and arranged as to cause the work to bear against the slowly moving wheel under the influence of gravity, said member maintaining the axis of the work at right angles to the path of movement of the operative surface of the grinding wheel and inclined relative to the path of movement of the operative surface of the other wheel so that the latter moves the work axially past the grinding wheel.

56. A centerless grinding machine comprising a base, fixed horizontal bearings thereon, a peripherally operative grinding wheel rotatably mounted in said bearings, means to rotate said wheel rapidly, bearings axially skewed relative to the grinding wheel and adjustable to vary the distance therefrom, a work-regulating wheel rotatably mounted in the movable bearings, said regulating wheel being wider than the grinding wheel, means to rotate the regulating wheel slowly, and an adjustably positioned member arranged to hold cylindrical work of various sizes between the wheels and in contact therewith axially parallel with the grinding wheel and permit the work to bear under the influence of gravity against the regulating wheel, said parts being so arranged that the work is axially fed and rotated by the regulating wheel before it contacts with the grinding wheel.

57. A centerless grinding machine comprising two peripherally opposed wheels, one a grinding wheel and the other a work-regu-

lating wheel located beneath the grinding wheel, means to rotate the grinding wheel rapidly and the work-regulating wheel slowly, means supporting the lower wheel for movement toward and from the upper wheel and permitting it to be skewed relative to the upper wheel, spaced members arranged to hold the work of round section between and in contact with the wheels and axially parallel to the axis of the grinding wheel, and means to adjust the distance between said members.

58. A centerless grinding machine comprising a base, fixed horizontal bearings on the base, a grinding wheel rotatably mounted thereon, a slide movable toward and from the grinding wheel, a work-regulating wheel rotatably mounted on the slide in opposition to the grinding wheel, means to rotate the grinding wheel rapidly and the regulating wheel slowly, means to hold work of round section between the wheels, and a screw feed to move the slide, said slide and screw feed being so arranged and constructed that all back lash in the screw is non-yieldingly taken up during the grinding operation and the regulating wheel may be moved precisely relative to the grinding wheel.

59. A centerless grinding machine comprising a base; a grinding wheel rotatably mounted in horizontal bearings; a regulating wheel having a peripheral face opposed to the operative surface of the grinding wheel; a yoke supporting said regulating wheel, said yoke being rotatable about an axis so that the path of movement of the operative surface of the regulating wheel is inclined relative to that of the grinding wheel; means to hold cylindrical work between and in contact with the peripheries of the two wheels; means to rotate the grinding wheel rapidly; and means to rotate the regulating wheel slowly to determine the rate of rotation of the work, said regulating wheel rotating and feeding the work axially past the grinding wheel while being ground by the latter, said parts being so arranged that the work will rest, under the influence of gravity, against the regulating wheel during the grinding operation.

60. A centerless grinding machine comprising a base, horizontal bearings thereon, a peripherally operative grinding wheel rotatably mounted in said bearings, a member mounted on the base to slide in a vertical direction toward and from the grinding wheel, a yoke carried on said slide, said yoke being rotatable about vertical axis, a peripherally operative regulating wheel rotatably mounted in the yoke in peripheral opposition to the grinding wheel, means to hold work of round section between and in contact with the peripheries of the wheels and constructed to permit the work to bear downwardly against the regulating wheel under the influence of gravity, and means to rotate the grinding wheel rapidly for grinding and the regulating wheel slowly for governing the rotation of the work, said regulating wheel acting, when said yoke is swung about said vertical axis sufficiently to create an angle between the axes of the regulating wheel and the work, to feed the work axially past the grinding wheel as it is being ground by the latter.

61. A centerless grinding machine comprising a base, two sets of horizontal bearings thereon, two peripherally operative abrasive wheels mounted in the bearings in peripheral opposition, means to rotate one wheel rapidly to grind the work, means to rotate the other wheel slowly to regulate the work rotation, a member mounted on the base and adapted to hold the work of round section in contact with said wheels and axially parallel with the grinding wheel, and means for adjusting the position of said member while maintaining the work axially parallel with the grinding wheel.

62. A centerless grinding machine comprising a grinding wheel, a work-regulating wheel having an operative surface which is wider than that of the grinding wheel, means to rotate the grinding wheel at a grinding speed, means to rotate the regulating wheel at a work-rotation-controlling speed, and means for holding work of round section between and in contact with the opposed operative surfaces of said two wheels and for holding the work in contact with that portion of the surface of the regulating wheel that projects beyond the operative surface of the grinding wheel.

63. In a grinding machine, in combination, a peripherally operative grinding wheel, a peripherally operative regulating wheel positioned substantially underneath said grinding wheel, means for rotating said grinding wheel at a grinding speed, means for rotating said second-mentioned wheel at such a slow speed that it controls the rotation of work of round section interposed between the two wheels, means for holding work in operative relation to the adjacent operative surfaces of said two wheels, and means adapted to permit adjustment of said work-holding means so that the axis of the work falls to one side of a line connecting the centers of the two wheels.

64. In grinding apparatus, means forming a four-sided grinding throat comprising, in combination, a grinding wheel adapted to be rotated at a relatively high speed, a regulating wheel positioned underneath the grinding wheel and adapted to be rotated at a relatively low speed, said wheels being rotated to present adjacent operative surfaces traveling in opposite directions, and two substantially horizontally spaced members extending between said two wheels for receiving therebetween and holding work of round section in operative relation to the adjacent operative surfaces of said wheels, said regulat-

ing wheel controlling the rotation of the work while the grinding wheel performs the grinding operation thereon.

65. In grinding apparatus, means forming a four-sided grinding throat comprising, in combination, a grinding wheel adapted to be rotated at a relatively high speed, a regulating wheel positioned underneath the grinding wheel and adapted to be rotated at a relatively low speed, said wheels being rotated to present adjacent operative surfaces traveling in opposite directions, two substantially horizontally spaced members extending between said two wheels for receiving therebetween and holding work of round section in operative relation to the adjacent operative surfaces of said wheels, said regulating wheel controlling the rotation of the work while the grinding wheel performs the grinding operation thereon, and means relating said work-holding members and said regulating wheel so that there exists an inclination between the path of travel of the work along one of said work-holding members and the path of travel of the operative surface of said regulating wheel to cause the latter to feed the work in an axial direction.

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