July 30, 1929. C. H. NORTON 1,722,386

CENTERLESS GRINDING MACHINE

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Fig. 12

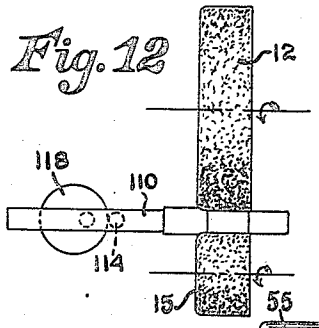


Fig. 7

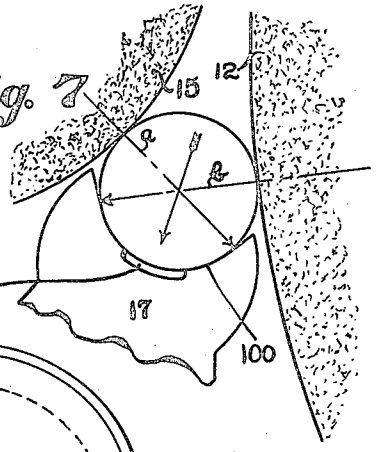
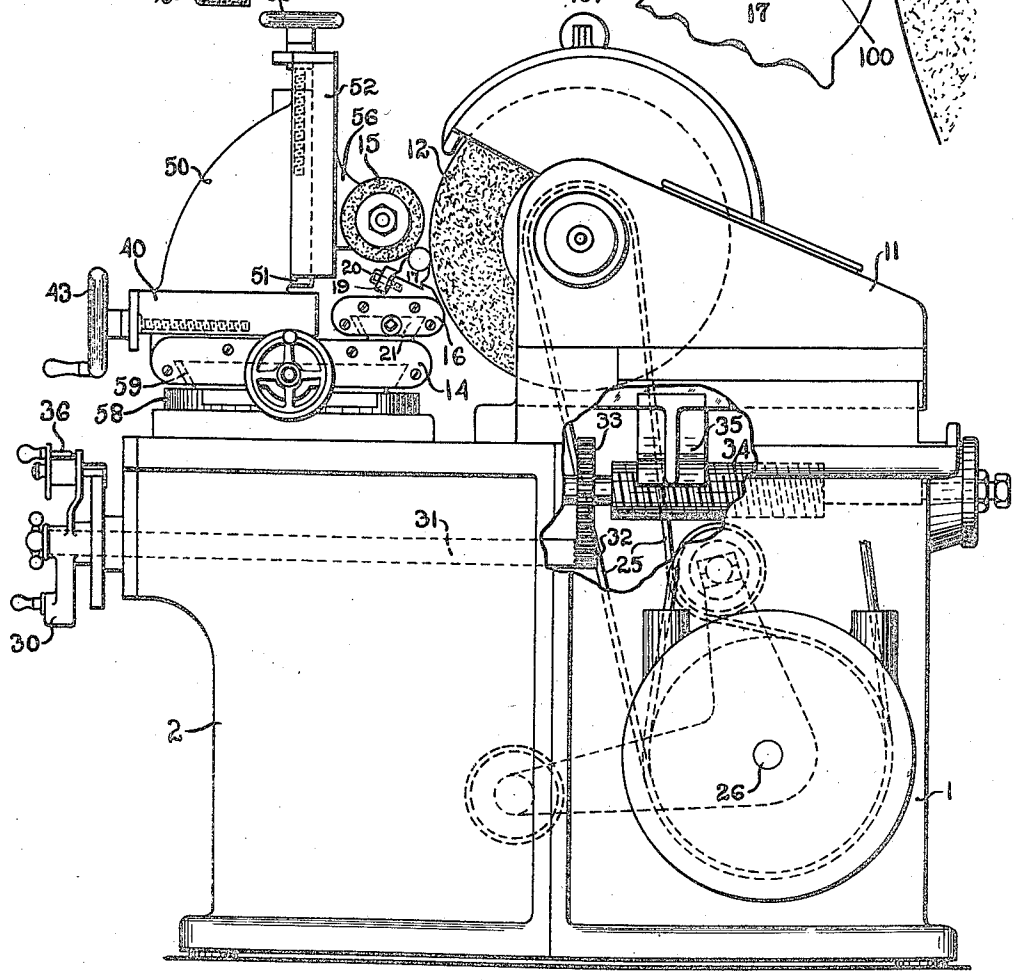


Fig. 1



Witnesses
Harold W. Eaton
Leah A. Seasions

Inventor
Charles H. Norton
By Clayton E. Jenks
Attorney

July 30, 1929. C. H. NORTON 1,722,386

CENTERLESS GRINDING MACHINE

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Fig. 10

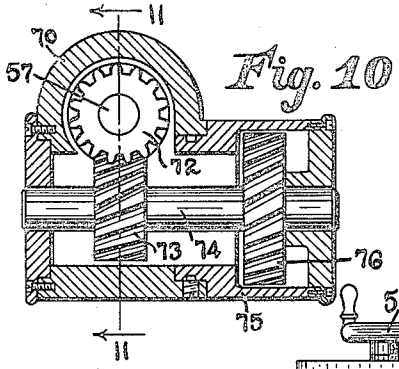


Fig. 11

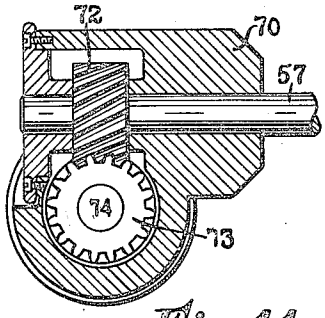
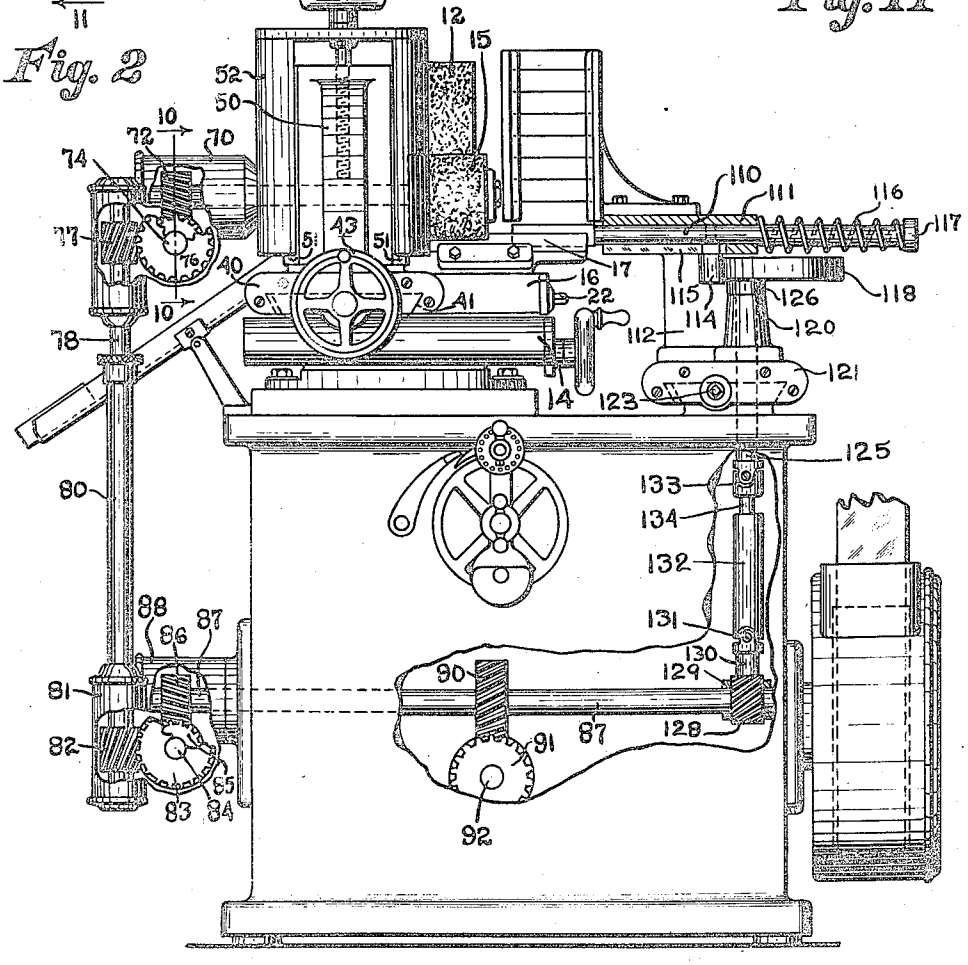


Fig. 2



Witnesses
Harold W. Eaton
Leah A. Sessions

Inventor
Charles H. Norton
By Clayton R. Sanders
Attorney

July 30, 1929. C. H. NORTON 1,722,386

CENTERLESS GRINDING MACHINE

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Fig. 8

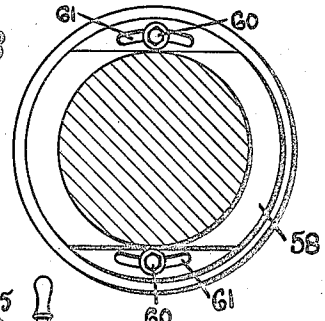
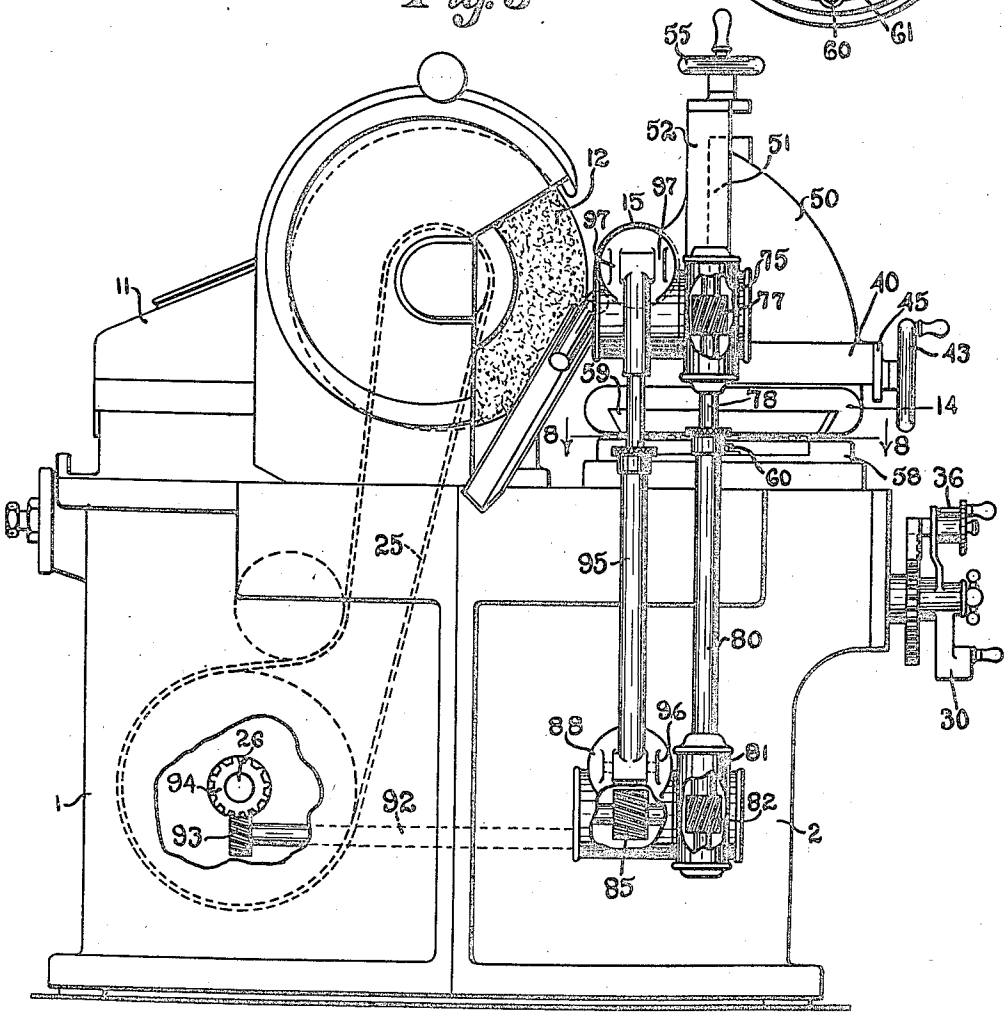


Fig. 3



Witnesses
Harold W. Eston
Leah A. Sessions

Inventor
Charles H. Norton
By Clayton R. Jenkins
Attorney

July 30, 1929. C. H. NORTON 1,722,386

CENTERLESS GRINDING MACHINE

Filed Nov. 21, 1922 5 Sheets-Sheet 4

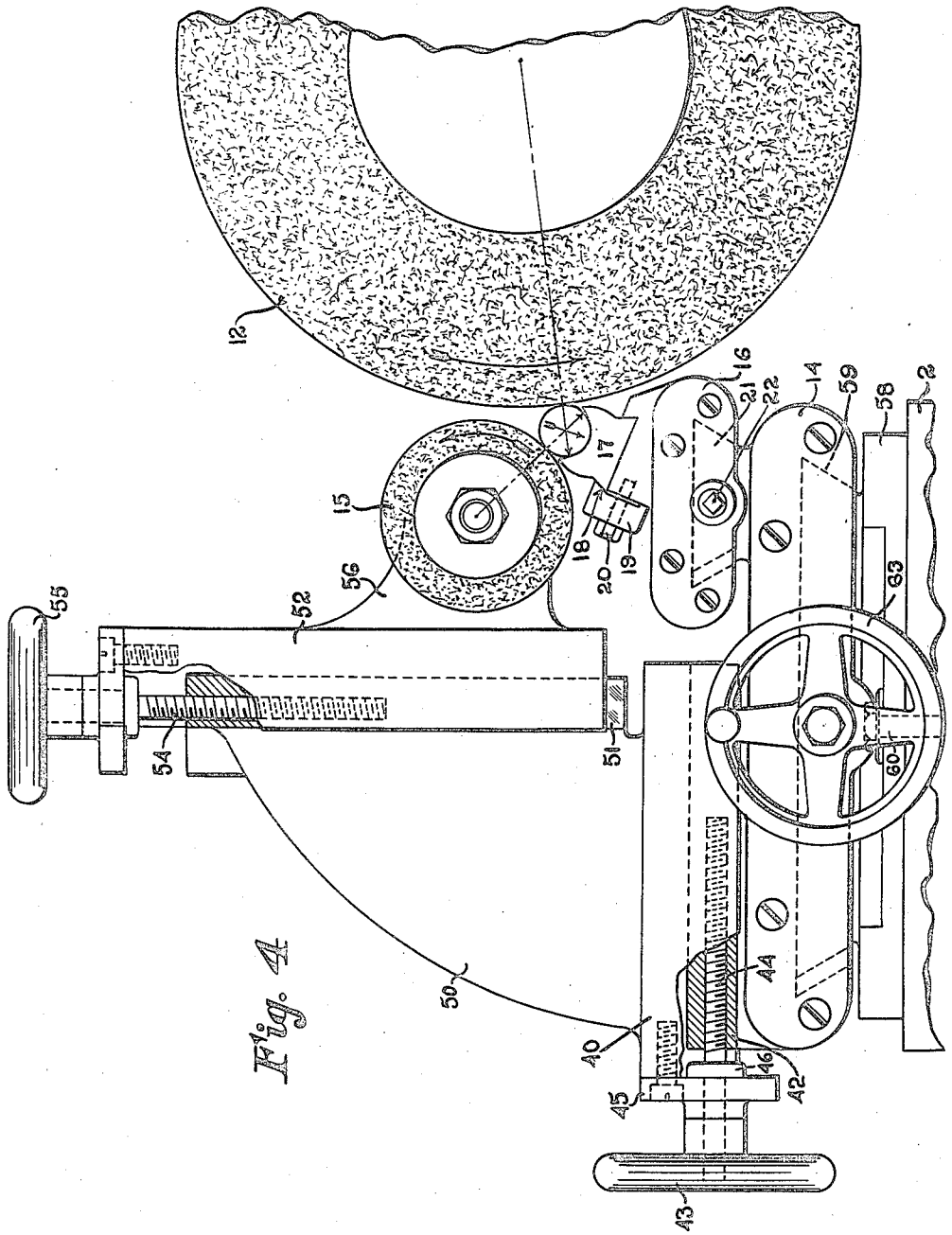


Fig. 4

Witnesses
Harold W. Eaton
Leah A. Sessions

Inventor
Charles H. Norton
By Clayton P. Jenkins
Attorney

July 30, 1929. C. H. NORTON 1,722,386

CENTERLESS GRINDING MACHINE

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Fig. 6

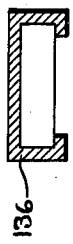


Fig. 5

Fig. 9

Witnesses
Harold W. Eaton
Leah A. Sessions

Inventor
Charles H. Norton
By Clayton R. Jenks
Attorney

Patented July 30, 1929. 1,722,386

UNITED STATES PATENT OFFICE.

CHARLES H. NORTON, OF PLAINVILLE, CONNECTICUT, ASSIGNOR, BY MESNE ASSIGNMENTS, TO CINCINNATI GRINDERS INCORPORATED, OF CINCINNATI, OHIO, A CORPORATION OF OHIO.

CENTERLESS GRINDING MACHINE.

Application filed November 21, 1922. Serial No. 602,451.

My invention relates to grinding apparatus and more particularly to a centerless grinding machine for automatically grinding objects of round cross-section, such as cylindrical objects, for example, to the same radius.

As conducive to a clearer understanding of certain features of this invention it might at this point be noted that my invention is directed toward and includes certain improvements upon the heretofore known and highly advantageous cylindrical centerless grinding machine in which two opposed abrasive wheels, having the work supported therebetween, are so driven that one is rotated at a high speed and serves as a grinding wheel and the other is rotated slowly to control the rotation of the work; by having the path of travel of the operative surface of the controlling wheel tilted relative to the path of travel of the work along the intermediate work support, the control wheel acts to feed the cylindrical work in an axial direction and hence past the operative surface of the grinding wheel. Where the two wheels operate by way of their peripheries and hence are peripherally opposed, this feeding action by the control wheel may be achieved by tilting the axis of the latter wheel relative to the axis of the cylindrical work held in operative relation to the two wheels by the work support. Such a tilted relation results in requiring that the surface of the regulating wheel be slightly concave in order that it may contact with the work in a straight line while at the same time achieving the feeding action above described; the trueing of the control wheel into this form gives rise in practice to certain difficulties. One of the objects of this invention is to provide an apparatus of the above-mentioned character in which such difficulties may be avoided and overcome in a thoroughly practical and dependable manner.

Another object of this invention is to provide a grinding apparatus of the above-mentioned character in which a number of thoroughly practical advantages over known types of centerless grinding machines may be realized and to provide a grinding apparatus in which, for example, the length of time during which a work piece is subjected to the action of the grinding wheel need not be limited by the feeding action of the control wheel but, moreover, may be predetermined to meet the varying conditions of practical use. Another object is to provide an apparatus of the above-mentioned general character in which the work to be operated upon is moved axially through the grinding throat formed by the grinding wheel and the work control wheel, and, moreover, by mechanism fully automatic throughout and of thoroughly dependable and efficient action. Another object is to provide a grinding machine of the above-mentioned character capable of performing a number of successive different grinding operations upon the work pieces but in a manner free from detrimentally affecting the control of the rotation of the work pieces by the control wheel. More particularly, another object of my invention is to provide an automatic centerless grinding machine which will move the work relatively slowly into the grinding throat and into full contact with the grinding wheel, permit the work to remain longitudinally stationary, and then move the work in an axial direction out of the grinding throat, all while the work is being rotated by the work rotating wheel.

Another object of this invention is to provide a grinding apparatus well adapted to perform heavy duty grinding but in a manner adapted to produce a high degree of accuracy and a highly finished surface on the completed work piece. Another object is to provide a centerless grinding machine of such a mode of operation that the sometimes unavoidable spring of the various parts of the apparatus is prevented from affecting high accuracy and uniformity of grinding action.

Another object is to provide a grinding apparatus of the above-mentioned character which will be of thoroughly practical action, rugged construction, and capable of being economically constructed and oper-

ated, and to provide such an apparatus capable of being readily adjusted to grinding various sizes and shapes of work rapidly and with the desired degree of precision. Other objects will be in part obvious or in part pointed out hereinafter.

The invention accordingly consists in the features of construction, combinations 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 one of various possible embodiments of my invention,

Figure 1 is a front view of the apparatus, certain parts, however, being removed or broken away in order to show certain features of the construction more clearly;

Fig. 2 is an end view of the apparatus as seen from the left of Fig. 1;

Fig. 3 is a rear view of the apparatus and also shows the apparatus as seen from the left of Fig. 2;

Fig. 4 is an enlarged front view showing particularly a preferred relation between the wheels, work support and work and also a preferred form of mounting for the work control wheel;

Fig. 5 is a detail view on an enlarged scale of the upper portion of the apparatus as seen from the right in Fig. 1 but with the grinding wheel and the mounting of the latter removed;

Fig. 6 is a horizontal sectional view taken on the line 6—6 of Fig. 5;

Fig. 7 is a diagrammatic view on an enlarged scale showing a preferred form of work support and a preferred relation between the latter and the two wheels;

Fig. 8 is a horizontal sectional view on the line 8—8 of Fig. 3 showing a possible arrangement for swiveling the work rotating wheel;

Fig. 9 is a fragmentary plan view of the plunger mechanism shown in Fig. 5 but on a smaller scale than that of the latter figure;

Fig. 10 is an enlarged sectional view taken on the line 10—10 of Fig. 2 showing a portion of the universal driving connections;

Fig. 11 is a sectional view on the line 11—11 of Fig. 10 showing the mounting of a casing for one of the driving gears; and

Fig. 12 is a diagrammatic view illustrative of a preferred mode of operation of the apparatus.

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

Referring now to the drawings and more particularly to Figs. 1 and 3, there is shown a main frame or supporting base for the apparatus, this frame being preferably made up of two parts 1 and 2. Upon the upper portion of the part 1 of the base there is mounted a carriage or slide 11 on which is rotatably mounted a grinding wheel 12, the carriage 11 being slidably mounted upon the base portion 1 by way of suitable guiding ways preferably of the usual V and flat type.

The construction of the mounting for the grinding wheel may be of any suitable type and may, for example, be substantially as shown in my Patent No. 1,261,156 of April 2, 1918. The grinding wheel 12 is mounted on a suitable spindle driven by belt 25 from a main drive shaft 26 rotatably supported in the base portion 1 of the apparatus. The spindle may be supported in bearings and oiled substantially in the manner as illustrated in my Patent No. 1,191,986 of July 25, 1916. In order to adjustably position the carriage 11 and hence the grinding wheel 12 along the ways coacting with the former, I provide the carriage 11 with a half-nut 35 upon the under side thereof adapted to engage and coact with the screw 34 which is rotatably supported in any suitable manner in the base portion of the apparatus. Conveniently, the left hand end of the screw 34 as seen in Fig. 1 is provided with a gear 33 adapted to be driven by a smaller gear or pinion 32 which is mounted upon the inner end of the shaft 31. The shaft 31 is rotatably supported in any suitable manner in the base portion of the apparatus and extends to the left thereof as seen in Fig. 1, terminating at its outer end in a crank arm 30 whereby the shaft 31 and hence the screw 34 may be manually rotated. Thus the carriage 11 and the grinding wheel 12 may be adjustably positioned along the ways supporting the carriage.

I may, however, supplement the manual control of the screw 34, as by means of the crank arm 30 above mentioned, by a suitable micrometer mechanism generally indicated at 36; this mechanism may take the form as described in detail in my Patent No. 762,838 of June 14, 1904. It may, however, at this point be noted that in the ordinary grinding operation performed by my apparatus and in which but a relatively small amount of stock is removed from the work, the adjusting mechanism above described, after having once been operated to predetermine the diameter to which the work is to be reduced, as will be more clearly described hereinafter, need be operated only to adjust the position of the grinding wheel from time to time as the wheel wears away.

Supported upon the base portion 2 of the apparatus, through appropriate intervening mechanism to be hereinafter more clearly described, and in peripheral opposition to the grinding wheel 12 is a wheel 15; wheel 15 is preferably made of abrasive material but is driven, in a manner more clearly hereinafter described, to drive the work or to

control the rate of rotation of the latter. In Figs. 4 and 5 the mounting of the control wheel 15 is more clearly shown, and referring to Fig. 5 it will be noted that the wheel 15 is mounted upon a spindle 57 which is rotatably supported in an appropriate bearing 56 forming part of a vertically adjustable slide 52. The slide 52 is shaped to coact with suitable ways 51 extending in a general vertical direction along one face of a standard 50, a screw 54 manually operable through the hand wheel 55 permitting the slide 52 and hence the wheel 15 to be adjusted vertically.

The standard 50 forms part of a slide 40 which is mounted to be adjustable horizontally in a direction toward or away from the grinding wheel 12 as seen in Fig. 4, and relative to a slide 14 which in turn is mounted for adjusting movement horizontally but in a direction crosswise of the peripheral operative surface of the grinding wheel 12. More specifically, the slide 14 is provided with a dove-tailed portion or way 42 along which the slide 40 and standard 50 may be adjusted by means of a screw 44 threaded into the dove-tailed portion 42 and passing at its outer end freely through a depending arm 45 on the slide 40; a hand wheel 43 is mounted upon the outer end of the screw 44 and abuts against the bracket 42, while a collar 46 on the screw 44 abuts against the other face of the bracket 45. Thus the manual rotation of the screw 44 permits the slide 40, and hence standard 50, to be adjustably moved in a direction toward or away from the grinding wheel 12.

The slide 14 is guided by the dove-tailed portion or way 59 along which the slide 14 may be adjustably positioned by means of the screw 64 (see Fig. 5) manually operable by way of the hand wheel 63. The dove-tailed portion or way 59 is formed in the upper face of a turntable 58 (Figs. 4 and 5) which is secured to the base portion 2 of the apparatus by means, for example, of the screws 60 (see Fig. 8) threaded into the base and passing through elongated arcuate slots 61 in the turntable. The mounting of the turntable 58 thus permits the latter with the mechanism carried thereby to be swivelled or adjusted about a vertical axis, the screws 60 permitting the turntable 58 to be locked into its adjusted position.

The control wheel 15 will thus be seen to be mounted to be adjustable vertically by way of the hand wheel 55, adjustable in a direction toward or away from the grinding wheel 12 as by means of the hand wheel 43 and adjustable also in a direction substantially lengthwise of the axis of the wheel 15 by means of the hand wheel 63. In the preferred embodiment of certain features of my invention the axis of the control wheel 15 is preferably parallel to the axis of the grinding wheel 12. Should it be desired, however, that the axes of the two wheels be arranged at an angle relative to one another, such an angular relation may be achieved by way of adjusting the turntable 58 about its vertical axis as hereinabove described.

The slide 14 is provided at its right hand end, as seen in Fig. 4, with a dove-tailed guideway 21 extending lengthwise of the axis of the wheel 15; upon this dove-tailed way 21 is mounted a slide 16 (Figs. 4 and 5) which may be adjustably positioned lengthwise of the ways 21 and hence longitudinally of the grinding throat of which the adjacent operative surfaces of the wheels 12 and 15 form a part, by means of a suitable nut and screw mechanism which may comprise a screw 22 threaded into the member 21 as is illustrated in Fig. 5. Upon the slide 16 is mounted a work support 17 for holding the rotating work during the grinding operation; the work support 17 may conveniently be secured to the slide 16 by means of a tongue and groove construction indicated generally at 18 in Fig. 4, and may be fixed in place by a clamping member 19 fastened to the slide 16 by means of cap screws 20. The relation of the parts is such that the work support 17 extends lengthwise and intermediate of the adjacent operative surfaces of the wheels 12 and 15, as will be clear from Fig. 5. Preferably the work support 17 is of a sufficient length to extend to either side of the opposed wheels so as to dependably support the work as it enters into and moves out of operative relation to the adjacent operative surfaces of the two wheels (see Fig. 5).

The wheels 12 and 15 are driven in directions as indicated in Fig. 4, the grinding wheel 12 being rotated rapidly to grind the work and the abrasive wheel 15 being rotated slowly so as to control the rotation of the work, the latter being held in operative relation to the two wheels by the work support 17. The wheel 15 may be rotated by any suitable mechanism, but I prefer to employ a universal driving mechanism constructed and arranged so that the desired drive of the wheel 15 may be maintained even though the latter may have its relation to the source of power changed as by way of any of the adjustments of the wheel 15 as hereinabove described. A preferred form of universal driving mechanism I have illustrated in Figs. 2, 3, 5, 10 and 11. Referring first to Fig. 3, there is provided in the base portions 1—2 of the apparatus a horizontally extending shaft 92 supported for rotation in any suitable way; shaft 92 is driven from the main driving shaft 26 by way of a pair of spiral gears 93—94. The right hand end of the shaft 92 as seen in Fig. 3 has mounted upon it a spiral gear

91 (see Fig. 2) which meshes with and drives a spiral gear 90 fixed upon a shaft 87 which extends transversely of the base of the apparatus and is mounted for rotation in suitable bearings. As is shown in Fig. 2, the shaft 87 extends through the base and to the rear of the apparatus and carries at its outer end (the left-hand end as seen in Fig. 2) a spiral gear 86 which meshes with and drives a spiral gear 85 fixed to a short shaft 84 to which is also secured a spiral gear 83. The shaft 84 is rotatably supported in a casing 88 which encases the gears 83, 85 and 86 and which in turn is mounted so as to swing about the shaft 87 as an axis. Spiral gear 83 meshes with and drives a spiral gear 82 (Figs. 2 and 3) which is secured to the lower end of an upwardly extending shaft 80. The lower end of the shaft 80 is rotatably supported by a casing 81 which encases the gear 82 and which in turn is mounted to swing about the shaft 84 as a pivot.

The shaft 80 is hollow and has extended into it in telescopic relation and splined thereto a shaft 78, from which the work rotating wheel 15 is driven by a driving connection substantially similar to that between the shaft 80 and the shaft 87.

This driving connection preferably includes a spiral gear 72 mounted upon the spindle 57 of the control wheel 15 (see Fig. 5), and meshing with the spiral gear 72 is a spiral gear 73 (see Figs. 10 and 11) which is secured to a shaft 74 rotatably supported in a casing 70 mounted, as is indicated in Fig. 11, to swing about the shaft 57 as an axis. Secured to shaft 74 is a spiral gear 76 which is driven by a spiral gear 77 mounted upon the upper end of the shaft 78. The upper end of shaft 78 is rotatably supported by a casing 75 which encases the gear 77 and which is pivotally mounted on the gear casing 70, as shown in Fig. 10, so that it may swing about the axis of the shaft 74.

Thus the wheel 15 may be given any desired adjustment by way of the mechanism hereinbefore described and, assuming that it is adjusted vertically, as by the hand-wheel 55, it will be seen that the driving connection between the wheel 15 and the main driving shaft 26 is maintained due to the telescopic relation between the shafts 78—80. Also, should the wheel 15 be moved in a direction toward or away from the grinding wheel 12, as by manipulation of the hand-wheel 43 (see Fig. 3), the gear casings 75 and 70 swing about the shaft 57 as an axis, and the gear casings 81 and 88 may together as a unit swing about the axis of the shaft 87; moreover, this swinging action will be seen to take place without interference with the driving connections between the coacting spiral gears. Also, should the wheel 15 be moved in a direction lengthwise of its axis, as by manipulation of the hand-wheel 63 (see Fig. 5), the gear casing 81 with the shaft 80 simply swings about the axis of the shaft 84 while the shaft 78 with the gear casing 75 swings about the axis of the shaft 74, all without interfering with the driving connections between the respective gears. Thus the driving mechanism permits the giving of a universal motion of adjustment to the work rotating wheel 15 so that any desired adjustment of the latter may be accomplished, all while maintaining the driving connection between the wheel 15 and the main driving shaft 26.

In order to eliminate any possible strain upon the telescopic shaft 78—80 I provide a telescopic guide rod 95 (see Fig. 3) which is pivotally mounted at its lower end to the projections 96 on the gear casing 88 and is pivotally secured at its upper end to the projections 97 of the gear casing 70. Thus, as the work rotating wheel 15 is moved to make the necessary adjustments, the guide rod 95 will swing the casing 80 in accordance with the changed position of the casing 70 and thus relieve the drive shaft 78—80 of the strain or effort necessary to move the gear casing.

Upon the front and upper portion of the base portion 2 of the apparatus, that is, at the left-hand portion thereof as seen in Fig. 5 and at the right-hand portion thereof as seen in Fig. 2, I provide a dove-tailed member 122 extending in a direction transversely of the direction in which the work support 17 extends; this member 122 slidably guides a slide 121 which has appropriate undercut ways for coaction with the dove-tailed member 122. The slide 121 carries a standard 112 which is provided at its upper portion with a sleeve-like member 111 extending in a direction lengthwise of the work support 17. The member 111 forms a bearing within which a plunger 110 is slidably guided.

The plunger 110 is provided at its outer end with an enlarged head 117 and between the head 117 and the portion 111 the plunger 110 carries and is encircled by a helical spring 116 which tends to expand and thus to move the plunger 110 in a direction toward the right as seen in Fig. 2. The sleeve member 111 is slotted as at 115 (Fig. 2) along its under side, and through the slot 115 projects a pin or cam follower 114 secured to the plunger 110. The cam follower 114 coacts with a cam 118 which is rigidly attached to and driven by a shaft 125 which extends through a post 120 carried by the slide 121 and suitably bored to provide a bearing for the shaft; a collar or enlarged portion 126 of the shaft 125 rests on the top of post 120. The spring 116 holds the cam follower 114 of the plunger 110 in contact with the peripheral cam sur-

face of the cam 118. The cam 118 is so shaped as to give the desired stroke to the plunger 110 and, as illustrated in Fig. 9, the cam may be of circular outline but eccentrically mounted upon the shaft 125; it will be understood, however, that any suitable means may be employed for moving the plunger 110 forward at any desired rate or velocity or at a changing rate.

The shaft 125 is conveniently driven at a suitable speed from the shaft 87 mounted in the base of the machine. Preferably shaft 87 carries a spiral gear 128 which meshes with a mating spiral gear 129 carried on a vertical shaft 130 which is suitably mounted in bearings which for the sake of greater clarity of illustration are not shown in the drawings. A universal joint 131 connects the shaft 130 with the hollow shaft member 132 within which slides or telescopes a shaft 134 connected by a universal coupling 133 to the shaft 125. Suitable means may be provided for moving the slide 121 relative to the base portion of the machine and may comprise a screw-threaded member 123 (Fig. 2) the construction and operation of which may be similar to those of the adjusting mechanisms for the other slides hereinbefore described and also shown in the drawings. Thus the plunger 110 may be adjustably positioned relative to the work support 17, as by adjustment of the slide 121, though it may at this point be noted that the various adjustable slides supporting the regulating wheel 15, work support 17 and grinding wheel 12 may be adjusted individually or in coaction with each other and with the adjustment of the plunger 110 to achieve the desired interrelation of the several parts of the apparatus. The flexible and telescopic driving connection between the shaft 87 and the cam 118 (Fig. 2), however, will be seen effectively to maintain the drive of the cam throughout whatever changes of position are given the plunger 110 and the cam 118. The diameter of the plunger 110 is preferably slightly less than that of the work pieces to be operated upon.

Coacting with the forward portion of the plunger 110 is a magazine 136 better shown in Figs. 5 and 6 mounted upon the upper portion of the standard 112. The magazine 136 extends vertically, is open-ended at the bottom where it substantially overhangs the front end of the work support 17 and is shaped and adapted to receive a suitable number of round work pieces 140 (Fig. 5) with their axes extending in the direction of the plunger 110 and one work piece on top of another.

In so far as certain broader features of my invention are concerned, the work-engaging surface of the work support 17 may be of any suitable form or shape but in accordance with certain other features of my invention I prefer to form the work-engaging surface substantially in the form of a portion of a cylinder whose radius is the same as that to which the work piece is to be reduced and whose axis extends lengthwise of the grinding throat. In Fig. 7 I have indicated this preferred form of cylindrically concaved surface at 100 and I may cut away a portion of this surface as indicated at 101. Also, I preferably form the outer portions of the concave surface 100 so that they veer off as substantially tangential planes so as to readily accommodate and hold oversized work pieces. When using this preferred form of work rest the parts thereof are preferably so proportioned and located relative to the two abrasive wheels 12 and 15 that lines drawn from the centers of the abrasive wheels respectively through the center of the work pieces will intersect these tangential planes as shown by the arrows *a* and *b* in Fig. 7. As is further shown in Fig. 4, I preferably so relate the two wheels to the work support 17 that the center of a work piece in the grinding throat formed thereby is positioned beneath a line connecting the centers of the wheels though it is to be understood that this feature is not essential in so far as certain broader aspects of my invention are concerned. Also, it is to be understood that when the apparatus is to operate upon a different size of work piece, the work support 17 will be replaced by one whose surface 100 (Fig. 7) has an appropriate and correspondingly different radius of curvature and that suitable adjustments of the wheels relative to the work support may be made to suit the grinding throat to the new size of work to be operated upon.

Considering now the operation of the apparatus, it is first to be noted that the work-rotating wheel 15 and the grinding wheel 12 are rotated in the direction of the arrows shown in Fig. 4 and are thus made to present adjacent operative surfaces traveling in opposite directions and being peripherally opposed are rotated about their axes in the same direction. The operative surface of the grinding wheel 12 will be seen to travel downwardly toward the work support 17 and that of the work-rotating wheel 15 upwardly or away from the work support 17. The grinding wheel 12 is driven at a rapid rate appropriate for grinding, and the smaller wheel 15 is driven at a slow rate so that it serves to control the rate of rotation of the work; the work-rotating wheel forms in one sense a part of the work support to prevent vibration of the work piece which is being ground by the grinding wheel 12.

The work support 17 is preferably made about three times as long as the work piece to be operated upon and, as is clearly shown in Fig. 5, it not only extends between the wheels but also projects beneath the maga-

zine 136 on one side of the wheels and extends beyond the wheels on the other side thereof. The rear or right-hand end of work support 17 (Fig. 5) has substantially aligned with it a downwardly inclined chute 142 mounted on supports 143 and 144 arranged with suitable joints which will permit movement of the various slides and yet hold the chute in proper position.

Assuming the cam 118 to be in the position shown in Fig. 5, plunger 110 is retracted by spring 116 and permits the lowermost work piece of the stack of work pieces 140 in the magazine 136 to drop upon the forward end of the work support 17, the concaved surface 100 of which conveniently acts to hold the work piece from rolling off of the work support 17. Cam 118 advances the plunger 110 to the right as viewed in Fig. 5, the plunger 110 pushing the work along the support 17 and in between the two wheels, the control wheel 15 rotating the work piece while the grinding wheel 12 performs a grinding operation thereon and performing a progressive grinding operation thereon substantially from the forward end of the work piece to the rear end thereof. The plunger 110 is thereupon retracted, leaving the work piece at rest between the two wheels while the grinding wheel performs a second grinding operation thereon during which the grinding wheel grinds its way out as it were until the spring of the apparatus has been taken up and the wheel has substantially finished its grinding action. The retraction of the plunger 110 permits another or second work piece to drop out of the magazine 136 and the subsequent advance of the plunger 110, all under the control of cam 118, causes the second work piece to engage the above-mentioned or first work piece which is still at rest though rotating between the wheels, whence the plunger 110 causes the two axially aligned work pieces to be moved along the work support 17. The first work piece is thus moved out of the grinding throat and during this longitudinal movement past the grinding wheel the latter removes all wheel marks and puts a polished finish on the surface of the work piece. During this action the second work piece is moved into the grinding throat during which movement the grinding wheel performs thereon the progressive grinding operation as above described in connection with the first work piece. These cycles are repeated as will now be clear, and at each cycle a new work piece drops out of the magazine 136 while a finished work piece which has the above-described three grinding operations performed thereon is pushed off of the work support 17 and discharged from the apparatus by way of the chute 142.

In Fig. 12 I have shown diagrammatically a portion of the apparatus illustrating how the above-described grinding operations may be carried on if desired; as indicated in Fig. 12 the abrasive wheels may be wider than the length of the work if desired so that the corners of the two wheels at the entry end of the grinding throat may become rounded due to wear where the work first contacts with the wheels but still provide substantially parallel lines of contact throughout the whole extent of the work piece when the latter has been brought into full contact with the wheels. It might also be noted that I may effectively force an over-sized work piece along the work support 17, the grinding wheel effectively reducing the work piece progressively as the latter passes the front corner of the grinding wheel.

It will be seen that I am enabled to subject the work piece to three successive stages of grinding, all by way of the same apparatus. I may cause the apparatus to take a heavy initial or roughing cut during the first grinding stage when the work piece is forced into the grinding throat; this it will be seen I achieve by feeding the work along its axis into contact with the corner of the peripheral face of the grinding wheel 12 and then moving it at a substantially uniform rate until it has come into full contact with the grinding wheel whose face is preferably sufficiently wide to grind the work piece along its whole length. Then the work piece is permitted to remain longitudinally stationary but it continues to rotate under the control of the work-rotating wheel 15 and during this continuing rotation is ground along its entire length by the grinding wheel 12, the latter grinding its way out and substantially completing a rough grinding operation. The subsequent movement of the work piece out of the grinding throat provides, in the third stage, a polished and finished surface. All of these three operations will be seen to be performed by the same grinding wheel.

When a work support having the concave surface 100 (Fig. 7) is employed, I achieve the further advantage that during the grinding period when the work is longitudinally immovable the work gradually and by a series of progressive approximations approaches and finally achieves the shape and radius of the work supporting cylindrical surface 100; thereafter and during the finish grinding stage the work substantially fits the surface 100 and thus is carefully steadied while its surface is given the final finish. It is to be understood, however, that many features of my invention may be achieved without utilizing this preferred form of work-supporting surface.

It will thus be seen that there has been provided in this invention an apparatus in which the several objects hereinbefore noted

as well as many thoroughly practical advantages are successfully achieved. It will be seen that the apparatus is capable of a wide range of adjustment, is of thoroughly practical and rugged construction and action and 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 drawing is to be interpreted as illustrative and not in a limiting sense.

Having thus described my invention, what I claim as new and desire to secure by Letters Patent is:—

1. In a grinding machine, in combination, a grinding wheel; a support to hold round work in operative contact with said wheel and providing a path of travel for the work past the operative surface of said grinding wheel; means for rotating said grinding wheel; means for rotating the work on said support; and means to move the work in the direction of its axis and along the path of travel provided by said support, while said work is rotating, and into substantially full grinding contact with said grinding wheel, then to cause halting of the work on said support to permit it to be ground while rotating and remaining immovable in an axial direction, and thereafter to move the work, while being rotated and ground, along said support and out of operative relation to said wheel.

2. A centerless grinding machine comprising two peripherally opposed abrasive wheels, means to maintain work of round section in operative contact with the wheels, means to rotate said wheels, one rapidly and the other slowly to grind and rotate the work, and means independent of said wheels to move the work along its axial line into operative contact with said wheels to initiate rotation and grinding of the work, thereafter permit the work to be ground while rotating but remaining longitudinally immovable and then move the work axially while being ground until out of engagement with said wheels.

3. A centerless grinding machine comprising two peripherally opposed abrasive wheels having parallel axes, a support therebetween having a work supporting surface below a line joining the wheel centers, means to rotate said wheels in the same peripheral direction, one rapidly to grind the work and the other slowly to rotate the work, and automatically operated means to move the work axially parallel with the wheel axes into contact with the peripheral corners of said wheels, then gradually until in full contact with the peripheral wheel faces, then permit the work to remain longitudinally immovable while being ground and thereafter remove the work from engagement with said wheels.

4. A grinding machine comprising peripherally opposed abrasive wheels having parallel axes, means to hold cylindrical work between and in contact with said wheels, means to rotate the wheels, one rapidly and the other slowly, for grinding and rotating the work, and a reciprocatory plunger to pass a piece of work in an axial direction into grinding contact with and past the peripheries of said wheels.

5. A centerless grinding machine comprising a grinding wheel and a work regulating wheel having parallel axes and peripherally opposed grinding faces, a work support therebetween having a concave partial cylindrical surface of substantially the same radius as the finished work which is axially parallel with the wheel axes, means to supply pieces of work thereto, a plunger to move the work axially along said supporting surface and a power driven device to move said plunger.

6. A centerless grinding machine comprising opposed abrasive wheels, a work support to hold cylindrical work between and in contact with said wheels, means to rotate the wheels, one rapidly and the other slowly, to grind and rotate the work, means to provide a supply of work pieces and reciprocatory mechanism independent of said wheels to pass said pieces in succession axially into grinding contact with the faces of said wheels.

7. A grinding machine comprising a base, a grinding wheel mounted thereon, means to rotate said grinding wheel, a work support mounted on said base having a concave partial cylindrical surface of substantially the same radius as the finished work for holding the work against the periphery of said wheel, a slide mounted for transverse movement toward and from the work support, a work regulating wheel rotatably mounted on said slide, means to rotate said wheel for any position of the slide and means independent of said wheels to move the work axially for the grinding operation.

8. A grinding machine comprising a base having transverse ways, a slide movable on said ways, a grinding wheel rotatably mounted on the slide, a work support having a concave partial cylindrical surface axially parallel with said wheel, a slide mounted for movement toward and from the work support, a work regulating wheel rotatably mounted on said slide in opposition to the grinding wheel, means to rotate the grinding wheel rapidly and the other slowly to grind and rotate the work, and means independent of said wheels to move

a cylindrical piece of work positively on its axial line along said work supporting surface in contact with said wheels.

9. A grinding machine comprising a grinding wheel and a work regulating wheel in peripheral opposition, means to rotate the grinding wheel at a grinding speed and the regulating wheel at a speed and in a direction to control the rotation of work of round section interposed therebetween, a support to maintain the work between said wheels, means to move the wheels relatively toward each other and into contact with the work, means to adjust the work rotating wheel vertically so that it may be located adjacent the grinding wheel and axially above the work axis, and means independent of said wheels to pass a round work piece in a direction substantially parallel with its axis along the support into contact with said wheels.

10. A grinding machine comprising a grinding wheel and a work regulating wheel having parallel axes, means to rotate the grinding wheel at a grinding speed and the regulating wheel at a speed and in a direction to control the rotation of work of round section interposed therebetween, a work support having a concave partial cylindrical surface between said wheels but below a line connecting their centers, means to move the wheels relatively toward each other and into contact with the work, means to adjust the work rotating wheel vertically relative to the work, and positive means independent of said wheels to move a round work piece in a direction substantially parallel with its axis along the support during grinding.

11. A grinding machine comprising a base, a grinding wheel mounted thereon, a slide mounted on said base to move parallel with the grinding wheel axis, a work support on said slide having a concave partial cylindrical work supporting surface, a work regulating abrasive wheel mounted on said slide in peripheral opposition to the grinding wheel, means to rotate said grinding wheel at a grinding speed and the work regulating wheel at a speed and in a direction to control the rotation of work of round section interposed therebetween, and means independent of the wheels to pass the work positively along the work support for the grinding operation.

12. A grinding machine comprising a base, a grinding wheel rotatably mounted thereon, a work regulating wheel in peripheral opposition thereto, means to rotate said grinding wheel at a grinding speed and the work regulating wheel at a speed and in a direction to control the rotation of work of round section interposed therebetween, a work support between the wheels, means to move the work rotating wheel and the work support in a direction substantially parallel with the grinding wheel axis independently of each other and positive means to move a work piece of round section axially along the support in contact with said wheels.

13. A grinding machine comprising a rapidly rotatable grinding wheel, a slowly rotatable work regulating wheel axially parallel with and peripherally opposed to the grinding wheel, means to rotate the wheels, the grinding wheel rapidly and the regulating wheel slowly to respectively grind and rotate the work piece of round section interposed therebetween, a work support therebetween, means to adjust one of said wheels relatively to the other and the work, means to supply a succession of work pieces to the support in substantially axial parallelism with the wheel axes and means independent of the wheels to move a single piece of work axially and progressively into the grinding zone in contact with the wheel peripheries.

14. A grinding machine comprising a rapidly rotatable grinding wheel and a slowly rotatable work regulating wheel having their axes parallel and their peripheral faces opposed, a support therebetween having a concave partial cylindrical surface axially parallel with the wheel axes, means to adjust said wheels relative to the work, means to rotate the wheels, means to supply a succession of work pieces to and axially parallel with the work supporting surface and positively operated mechanism independent of the wheels to move said work pieces successively along their axial line into operative relation to said wheels.

15. A grinding machine comprising a grinding wheel and a work regulating wheel having parallel axes and peripherally opposed grinding faces, means to move one of said wheels relatively to the other, a work support between the wheels, means to move it relative to the wheels and positively actuated mechanism to move work along said support in grinding contact with said wheels for any position of the support.

16. A grinding machine comprising a grinding wheel and a work regulating wheel having opposed faces, a work support therebetween, which is adjustable about a vertical axis, means to rotate said wheels and positively actuated mechanism to move work along said support into operative relation to said two wheels.

17. A grinding machine comprising a grinding wheel, a table mounted to swivel about a vertical axis, a work regulating wheel and a work support on said table, means to move one of said wheels relative to said work support to adjust for different sizes of work, means to rotate said wheels and means positively actuated to move the work along said support for any position of the table.

18. A grinding machine comprising a

base, a rotatable grinding wheel transversely movable thereon, a lower slide on the base movable parallel with the grinding wheel axis, a removable support thereon having a work supporting groove parallel with the wheel axis, a transversely movable slide on said lower slide, a work regulating wheel mounted thereon axially parallel with the work, means for adjusting said work rotating wheel vertically relative to the work and positively actuated means to move the work axially along said groove.

19. A grinding machine comprising a base, a rotatable grinding wheel transversely movable thereon, a work regulating wheel peripherally opposed to the grinding wheel, means to move one of said wheels toward or away from the other, a removable support between said wheels arranged to hold the work in peripheral contact with said wheels, means to adjust said support longitudinally parallel with the wheel axes, means to adjust the work rotating wheel vertically, and positively actuated mechanism to move the work along said support for the grinding operation.

20. A grinding machine comprising a base, a grinding wheel mounted thereon, means to rotate said grinding wheel, a regulating wheel work holding means between said wheels adapted and arranged to hold work of round section in operative relation to said two wheels, a slide mounted for transverse movement toward and from the work support, said work regulating wheel being rotatably mounted on said slide, means to rotate said wheel at a speed and in direction to control the rotation of the work and operative for any position of the slide and a plunger mechanism to move the work axially for the grinding operation.

21. A grinding machine comprising a base having transverse ways thereon, a slide on said ways, a grinding wheel mounted on the slide, a work regulating wheel mounted in peripheral opposition to the grinding wheel, a work support having a concave partial cylindrical surface of the same radius as that of the finished work arranged to hold the work against the peripheries of said wheels, means to rotate said grinding wheel and regulating wheel at respective work-grinding and work-regulating speeds, and means independent of the wheels to move a piece of work positively along said work support during grinding.

22. A centerless grinding machine comprising an abrasive grinding wheel, a work regulating wheel opposed thereto, means to hold work of round section between and in contact with the active faces of said wheels, means to respectively rotate the regulating wheel slowly and the grinding wheel rapidly to rotate and grind the work and positively actuated mechanism independent of said grinding wheel which is constructed and arranged to move the work axially along said work holding means into operative relation to said two wheels and thereafter permit the work to remain longitudinally immovable while it is being operated upon.

23. A centerless grinding machine comprising a grinding wheel, a work regulating wheel opposed thereto, means to hold round work which is shorter than the width of the grinding wheel between and in contact with said wheels, means to rotate the regulating wheel slowly and the grinding wheel rapidly to respectively rotate and grind the work and positively actuated mechanism independent of said wheels to move a single piece of work axially into operative contact with said wheels and then permit the work to dwell while being ground.

24. A centerless grinding machine comprising an abrasive grinding wheel, a work regulating wheel opposed thereto, means to guide and hold a piece of work of round section into contact with the active faces of said wheels, means to rotate the regulating wheel slowly and the grinding wheel rapidly to respectively rotate and grind the work, means for adjusting the apparatus to accommodate different sizes of work and a positively actuated plunger mechanism constructed and arranged to push a single work piece substantially axially into operative contact with said wheels and thereafter out of the grinding zone.

25. A grinding machine comprising two peripherally opposed abrasive wheels having parallel axes, means to rotate one wheel rapidly to grind the work of round section and the other slowly to control the work rotation, a positioning member to hold round work between said wheels so that their axes are not in the same plane, a support to hold a work supply, and a positively operated reciprocatory plunger mechanism to move a cylindrical piece of work from said support and along said work positioning member in an axial direction into contact with the wheels for the grinding operation and thereafter move the work in the same direction out of the grinding zone.

26. In grinding apparatus, in combination, a grinding throat adapted for simultaneous grinding and rotating action upon work of round section and comprising at least three members, one of said members being in the form of a grinding wheel rotated at relatively high speed, another of said members being in the form of a regulating wheel rotated at relatively low speed and in a direction to present an operative surface traveling in a direction opposite from that of the adjacent grinding wheel surface and adapted thereby to control the rotation of the work, and another of said members being adapted to hold a work

piece in operative relation to said two wheels; a magazine for holding a supply of work pieces; mechanism for transferring a work piece from said magazine to said grinding throat; means for adjusting said grinding throat to accommodate work of different sizes; and means mounting said magazine adapted to permit adjustment thereof relative to said grinding throat.

27. In grinding apparatus, in combination, a grinding throat adapted for simultaneous grinding and rotating action upon work of round section and comprising at least three members, one of said members being in the form of a grinding wheel rotated at relatively high speed, another of said members being in the form of a regulating wheel rotated at relatively low speed and in a direction to present an operative surface traveling in a direction opposite from that of the adjacent grinding wheel surface and adapted thereby to control the rotation of the work, and another of said members being adapted to hold a work piece in operative relation to said two wheels; a drive shaft; means for effecting movement of a work piece relative to said grinding throat, means for adjusting said grinding throat to accommodate work of different sizes; means for adjusting said work moving means relative to said grinding throat, and a driving connection between said shaft and said work moving means operative throughout the adjustment of the latter.

28. In grinding apparatus, in combination, a grinding throat adapted for simultaneous grinding and rotating action upon work of round section and comprising at least three members, one of said members being in the form of a grinding wheel rotated at relatively high speed, another of said members being in the form of a regulating wheel rotated at relatively low speed and in a direction to present an operative surface traveling in a direction opposite from that of the adjacent grinding wheel surface and adapted thereby to control the rotation of the work, and another of said members being adapted to hold a work piece in operative relation to said two wheels; a magazine for holding a supply of work pieces; mechanism for transferring a work piece from said magazine to said grinding throat; means for predetermining the relation of said mechanism to said grinding throat; a drive shaft; and a driving connection between said shaft and said mechanism operative throughout the range of change of relation of said mechanism to said grinding throat.

29. In grinding apparatus, in combination, a grinding throat adapted for simultaneous grinding and rotating action upon work of round section and comprising at least three members, one of said members being in the form of a grinding wheel rotated at relatively high speed, another of said members being in the form of a regulating wheel rotated at relatively low speed and in a direction to present an operative surface traveling in a direction opposite from that of the adjacent grinding wheel surface and adapted thereby to control the rotation of the work, and another of said members being adapted to hold a work piece in operative relation to said two wheels; a plunger for moving a work piece relative to said grinding throat; means for changing the position of said work holding member relative to said grinding throat; a drive shaft; means for adjustably positioning said plunger relative to said work holding member; and a driving connection between said plunger and said shaft constructed to be operative throughout the range of change of adjustment of said plunger.

30. In apparatus of the character described, in combination, a grinding throat adapted for simultaneous grinding and rotating action upon work of round section and comprising three means, one of which means is in the form of a grinding wheel adapted to be rotated at a relatively high speed, another of said means being in the form of a regulating wheel adapted to be rotated at a relatively low speed and in a direction to present an operative surface traveling in a direction opposite from that of the adjacent grinding wheel surface, and the third of which means includes a member for holding work of round section in operative relation to said two wheels; and power driven means for causing movement of the work in a general direction lengthwise of the grinding throat.

31. In apparatus of the character described, in combination, a grinding throat adapted for simultaneous grinding and rotating action upon work of round section and comprising three means, one of which means is in the form of a grinding wheel adapted to be rotated at a relatively high speed, another of said means being in the form of a regulating wheel adapted to be rotated at a relatively low speed and in a direction to present an operative surface traveling in a direction opposite from that of the adjacent grinding wheel surface, and the third of which means includes a member for holding work of round section in operative relation to said two wheels; and power driven means for moving the work out of the grinding throat.

32. A centerless grinding machine comprising a work regulating wheel and a grinding wheel, means for positioning the work therebetween and peripherally opposed to the grinding wheel, means for rotating the

regulating wheel slowly and the grinding wheel rapidly respectively to rotate and grind the work, a reciprocating mechanism constructed and arranged to move the work pieces successively to a position between the wheels for grinding, and power operated means for actuating the mechanism cyclically to permit grinding successive work pieces to a predetermined size.

Signed at Worcester, Massachusetts, this 16th day of Nov., 1922.

CHARLES H. NORTON.